AD/A-000 082

INDEPENDENT RESEARCH AND INDEPENDENT EXPLORATORY DEVELOPMENT

Naval Electronics Laboratory Center
San Diego, California

1 September 1974

Approved for public release;
distribution unlimited

REPORT CONTROL SYMBOL NAVMAT 3920-1

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AD/A-000082

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NELC Technical Document 348 (TD 348)
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): ANNUAL REPORT FY 74 INDEPENDENT RESEARCH AND INDEPENDENT EXPLORATORY DEVELOPMENT
5. TYPE OF REPORT & PERIOD COVERED: Annual
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s):
8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Electronics Laboratory Center, San Diego, California 92152
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Z1, Z2
11. CONTROLLING OFFICE NAME AND ADDRESS: Director of Navy Laboratories
12. REPORT DATE: 1 September 1974
13. NUMBER OF PAGES: ~~81~~ 80
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
   - Electro-optical signal processing
   - Independent exploratory development
   - Independent research
   - Integrated circuits – ehf
   - Telecommunication – Acquisition
20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

This document is an overview of the NELC IR & IED programs. It summarizes the accomplishments achieved within each project in FY74. Longer articles are presented on three of the most significant projects – ehf Integrated Circuits, Programmable Electro-Optical Processor, and Telecommunication Equipment Low-Cost Acquisition Method (TELCAM).

80

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Foreword

The NELC discretionary program is aimed at increasing the Center's capability to perform the prime objective of a Navy laboratory: *to provide both timely leadership and assistance to others in meeting the most important needs of the Fleet in timely, cost-effective ways.*

The FY74 IR/IED program resulted from the recommendation to the Technical Director of the IR/IED Program Council, a group formed of one member from each technical department, the Analysis Group, and the Planning Office, and chaired by the head of the Advanced Technologies Office. Proposals originating from the technical staff were combined and grouped into larger, coherent efforts under designated program managers. In most cases there were participants from several divisions and more than one department.

The overall program can be divided into two categories -- both of which support our objective -- (1) new capabilities which will help us fulfill our role in providing the technological base for equipment of the future and (2) improved capabilities to achieve significant gains in equipment performance, reliability, and efficiency together with reductions in equipment size, weight, and life-cycle cost in the present.

Examples of the first category include:

- "Devices for New Frequency Regions" (Z193) was an interdivisional effort from which the first Highlight is taken.
- "Programmable Electro-Optical Processor" (Z197 and Z274), the second Highlight, combines IR and IED work that gives a capability to perform mathematical operations at very high speed. The scientists on this project work closely with signal processing engineers from the Naval Undersea Center on future applications.
- In the electro-optics area, application to communication problems continued with the development of "Narrowband Underwater Laser and Detector" (Z198) for underwater systems and "Optical Covert Communications Using Laser Transceivers (OCCULT)" (Z275).
- "Signal Processing Imager Using Charge Coupled Devices" (Z194) is a joint project with researchers of the Naval Undersea Center to exploit a new device to solve an old problem.

Projects in the second category include:

- "Telecommunication Equipment Low-Cost Acquisition Method (TELCAM)" (Z269). Described in the third Highlight article, this is directed toward achieving low-cost electronic equipment and device procurement through the development of alternatives to the use of military specifications.
- Reliability and maintainability will be increased through use of "C^3 Standard Packaging System" (Z273).
- Reduction of cost, weight, and size will be achieved through modularity in systems which will employ results of "Small Ship Command Control System (SSCCS)" (Z270); "Advanced Digital Communications Modules System (ADCOM)" (Z272); and "VERDIN Demodulator Design Study" (Z276).

The FY75 program follows the same philosophy. In particular, four of the Independent Exploratory Development projects are intended to give immediate solutions to important Marine Corps projects.

The NELC research and exploratory development accomplishments were featured exclusively in the May-June issue of the ONR *Naval Research Reviews.* All but two of the articles selected by the Center management to highlight past and current achievements were derived from the discretionary funded program.

H. T. Mortimer, Head
Advanced Technologies Office

Preceding page blank

ehf Integrated Circuits

D. L. Saul

This task was focused on extending the frequency capability of microwave integrated circuits (MICs) to permit operation at millimeter wavelengths (ehf). Experience has shown that MIC techniques that are successful when routinely applied in the conventional microwave bands (mainly below 12 GHz) are decidedly incompatible with conditions which prevail at ehf. Efforts were thus directed toward development of new technology needed to build MICs capable of performing well at ehf, and application of this technology toward the practical realization of components and circuits to provide a basis for full exploitation of MIC technology in the ehf range.

With conventional microwave integrated circuit (MIC) technology clearly inadequate for millimeter wavelength (ehf) applications, efforts were directed toward development of new technology to permit the potential of MICs to be fully realized at ehf. A hybrid approach utilizing microstrip fabricated on an irradiated polyolefin substrate material led to successful development of a number of components and circuits. These included several types of wideband microwave hybrid junctions, an MIC discriminator of the instantaneous frequency measuring (IFM) type, and integrated detectors having exceptionally low voltage standing wave ratio without loss of sensitivity.

The ehf MIC will provide the Navy with a needed capability in electronic signal measurement (ESM) and covert communications not now available.

In carrying this work forward within a context of projected Naval systems requirements, special emphasis was placed initially on development of wideband components suitable for surveillance receiver applications. Surveillance receivers play a key role in electronic signal measurement (ESM) programs, to which the Navy remains firmly committed. The potential uses of millimeter wave MICs extend, of course, over a much broader area, and benefits are expected to accrue in communications and other fields as well.

A hybrid MIC approach utilizing microstrip line was chosen for this work, this type of approach having been used with considerable success at lower microwave frequencies. With suitable adjustments of materials and techniques to meet the special conditions at ehf, microstrip demonstrates strong potential for practical circuit applications at frequencies well above the traditional frequency limitations of conventional microstrip designs. For purposes of this task, a substrate utilizing irradiated polyolefin dielectric was chosen. This material, manufactured and marketed under the trade name Polyguide, is obtained in sheets of 10-mil thickness, copper clad on both sides. The planar microstrip circuits are made by means of a photofabrication process.

Efforts were then directed toward development of a family of wideband, high-performance integrable components. Microwave hybrid junctions (or simply hybrids, not to be confused with hybrid ICs as distinguished from monolithic ICs) were afforded high priority for two reasons. First, they are critical components for discriminators used in instantaneous frequency measuring (IFM) surveillance receivers, and, second, they are by nature key building blocks in mixers, certain types of reflection amplifiers, and other application areas throughout the general microwave field.

Several types of hybrids were developed, with emphasis on extreme bandwidth capability. The various types include two- and three-branch couplers, conventional and reverse-phase hybrid rings, three-port terminated couplers of the Wilkinson type, and two-stage adaptations of the Wilkinson coupler for extremely wide-bandwidth applications.

Some examples of circuit integration are shown in figure 1. Three experimental discriminator circuits are shown, together with a type of reflection-canceling detector circuit that was developed to overcome voltage standing wave ratio (VSWR) problems usually found in conventional wideband detector mounts. The detector's three-branch coupler functions as a quadrature hybrid. The tapered line which doubles back on itself is a line termination to which a sheet of resistive film is attached. The detector circuit utilizes a pair of beam leaded Schottky barrier diodes. The hybrid's properties are such that power reflected from a pair of identical diodes will ideally add in phase at the termination and thus be dissipated, with the detector's input port remaining isolated

from the unwanted reflections. In laboratory tests, one of these MIC units easily outperformed a widely used commercial type of wideband detector, both in VSWR performance and sensitivity.

The discriminator circuits shown in figure 1 were developed for use in IFM receivers, a type frequently used for surveillance purposes in the microwave bands. The IFM type of discriminator is correctly termed a discriminator in the sense that its output varies as a function of input signal frequency. It is considerably more sophisticated than the discriminator type used for demodulating FM signals, however, and the two must not be confused. The IFM discriminator is usually a very wideband device, and is employed in connection with other IFM receiver circuitry to generate a polar spectrum display which allows continuous monitoring of all signals appearing within the band of coverage.

Figure 2 illustrates a microstrip discriminator of the IFM type. A later design which incorporates four integrated detectors of the reflection-canceling type is built on a 2-by-2-inch substrate. A subsequent circuit incorporates integrated detectors and incorporates all circuitry, including four detectors of the reflection-canceling type, on a 2-by-2-inch substrate.

ZR011.07
(NELC Z193)

Contact:
J. W. Carson or D. L. Saul
NELC Code 2300
(714) 225-6763 or 225-7095

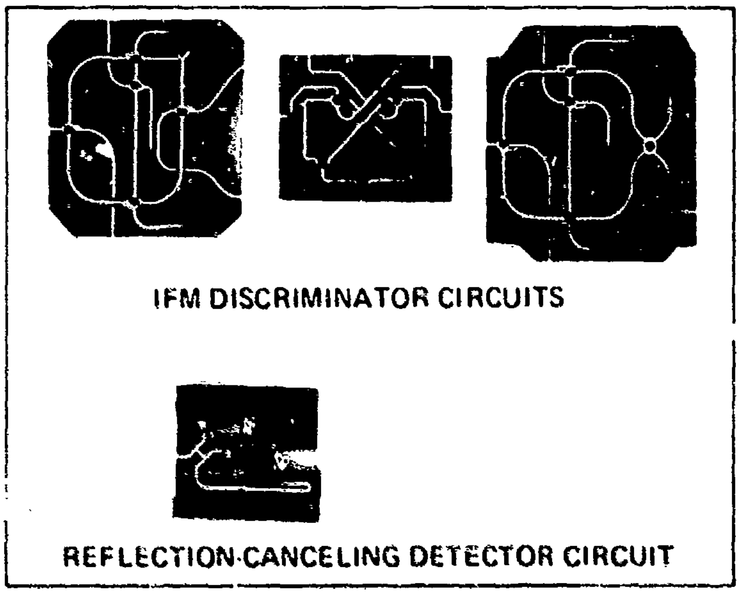


Figure 1. Examples of microwave integrated discriminator circuits and a reflection-canceling detector circuit for use in IFM receivers. The tapered line on the detector circuit is a line termination to which a sheet of resistive film is attached prior to use. (NELC photograph LSF 832-5-74)

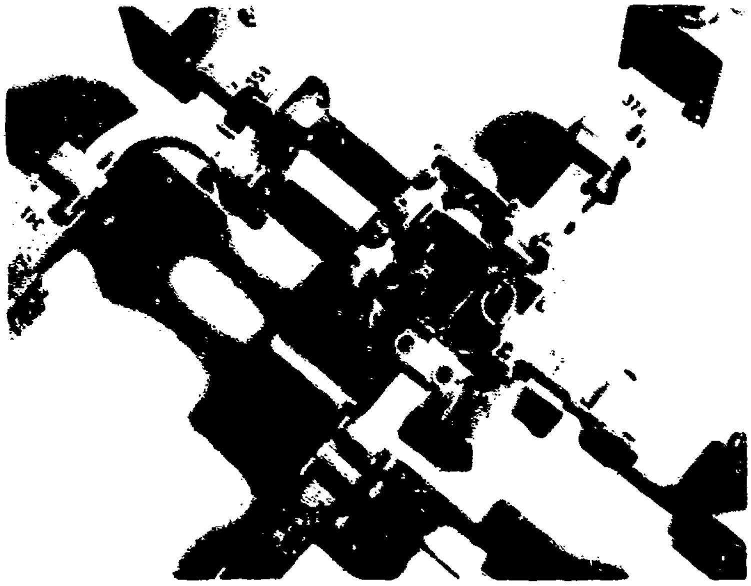


Figure 2 Microstrip discriminator in laboratory test fixture. External, wave guide mounted detectors are affixed for test purposes.

Programmable Electro-Optical Processor

R.P. Bocker, K. Bromley, and M.A. Monahan

The objective is a single electro-optical device programmable to perform any of a number of mathematical transformations at very high speed. Incoherent optical techniques provide real-time capability and relative freedom from vibration sensitivity. Programming is accomplished by mechanical switching from one photographic mask to another. This device is capable of a large variety of transformations and linear filtering operations.

The Navy has a broad interest in signal processing and is presently funding many programs to develop systems which perform transform and matrix operations. Examples include Fourier spectral analysis of signals, vocoding and bandwidth compression of voice, and numerous applications of transversal filtering in radar and sonar signal processing.

Present systems for performing matrix transformations are mostly all-digital electronic systems which require either time-consuming sequential computation of each point in the matrix or large amounts of hardware to achieve a degree of parallelism in operation. Most of these processors are hard-wired to perform a particular sequential algorithm and are therefore limited to performing only one type of transformation.

The objective of the NELC program in electro-optical signal processing is to develop a single electro-optical device which is programmable to perform any of a number of mathematical transformations at very high speed. The optical, fully-parallel nature of the device allows computation of very large transformations almost instantaneously in a unit which can be significantly smaller and less complex than existing systems.

The use of optics in signal processing introduces two important features. The first is an extremely fast multiplication rate. Multiplication of one analog value by another occurs in the time required for light to pass through an optical transparency -- typically a picosecond. The second is parallel processing capability. The two-dimensional nature of light propagation allows many one-dimensional operations to be performed simultaneously.

Since the advent of the laser, much effort has been expended in applying *coherent* optical techniques to signal processing in order to utilize the separate control of amplitude and phase obtained. Many worthwhile applications are in view and much promising research in these areas is underway. In many applications, however, efforts are currently thwarted by (1) vibration sensitivity due to the interferometric nature of many techniques, and (2) lack of a real-time input material sufficiently developed for use in a cost-effective, compact, off-the-shelf system.

To retain the features of fast multiplication rate and parallel operation while bypassing the problems of vibration sensitivity and lack of real-time input capability, the authors chose to pursue a different tack -- to investigate *incoherent* optical techniques. Results to date have been promising (ref 1–3). Two early exploratory development models were designed to cross-correlate simultaneously a "live" input signal with a large reference library of stored signals. These were applied to the problems of automatic passive sonar classification and active sonar detection and localization (ref 1 and 2). The present system is capable of a large variety of linear transformations and linear filtering operations. The basic concept of the technique is shown and described in figure 1. In mathematical terms, if we consider the electrical input signal modulating the light-emitting diode (LED) to be a column vector B of sampled data points, the mask to represent a matrix A, and the analog values serially read out of the charge coupled device (CCD) as a vector C, then it can be shown that this device performs the vector-matrix multiply operation (ref 3):

$$C = AB \text{ or } c_m = \sum_{n=1}^{N} a_{mn}b_n, \; m = 1, 2, 3, \ldots, M$$

Some examples of operations which can be performed are linear filtering, derivative operations, correlation, convolution, Fourier transforms, Laplace transforms, Walsh-Hadamard transforms, Z-transforms, and Mellin transforms. In fact, by simply replacing the photographic mask (the matrix A) in the above-described system, it can be converted, for example, from a Walsh transform device to a Z-transform device. Thus, it is mechanically programmable. The method of designing the masks is described in reference 3. One of these masks is shown in figure 2; this mask, reduced to 35-mm format, is that used to generate the real and imaginary coefficients of a Fourier transform of the input data.

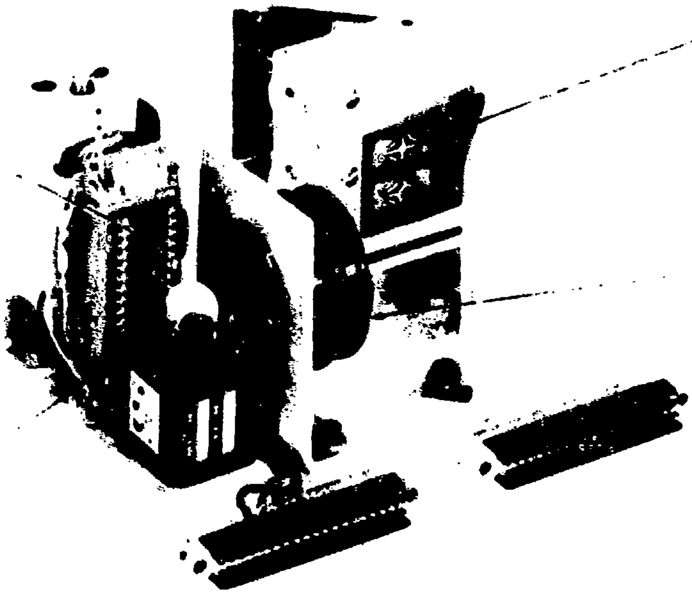


Figure 1. Present implementation of programmable electro-optical processor. The electrical input signal modulates the radiance of a light-emitting diode (LED) (not visible here) as a function of time. The LED is imaged by a Fresnel condensing lens (not visible) into the entrance aperture of an imaging lens. The mask, photographic transparency (1), is placed in this light beam immediately after the condensing lens. The mask has the form of a linear array of horizontal channels, each channel having a different spatial variation in intensity transmittance corresponding to some desired function. The imaging lens (2) images this transparency, via a scanning mirror (3), onto a vertical row of integrating detectors, a line-array charge coupled device (4). The scanning mirror causes the image to repetitively translate horizontally, with constant velocity, across the face of the CCD array. The CCD integrates this intensity-modulated moving image during the mirror sweep, and the resultant values are read out during the mirror's return.

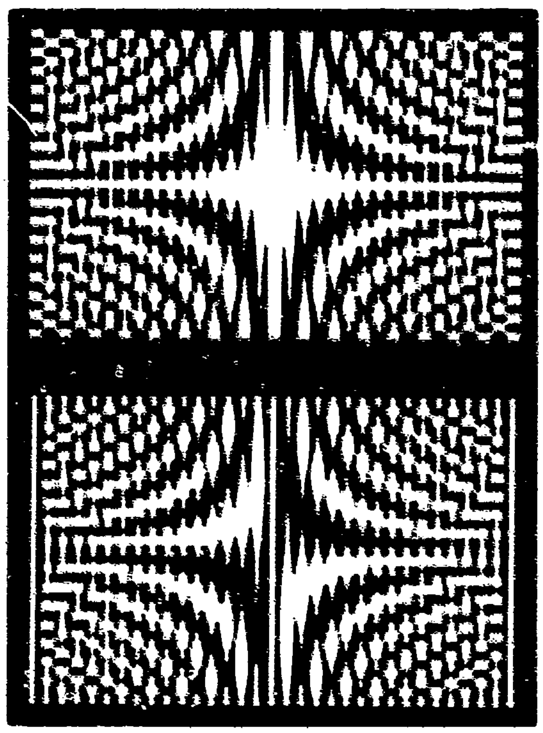


Figure 2. Photographic Mask. When used in the processor, the upper and lower halves produce the real and imaginary components of the Fourier transform coefficients of the input data. The horizontal length of the transparent area of each mask element is proportional to (1 + cos ω) for the upper half and (1 + sin ω) for the lower half; each horizontal line corresponds to a different ω.

A second-generation electro-optical processor incorporating a two-dimensional CCD array as the integrating, scanning, and read-out device was designed in FY74 and will be built in FY75. With properly timed clocking sequences, the scanning operation can be performed entirely within the CCD chip, thereby eliminating the need for a scanning mirror. Such a system – composed of only an LED, a condensing lens, a replaceable mask, and a two-dimensional CCD array – will form an extremely compact, rugged system, with no moving parts, for performing vector-matrix operations at very high speed. The size of the largest allowable matrix is limited to that of the CCD array (100-by-100-element CCDs are off-the-shelf items today, and 1000-by-1000-element CCDs are envisioned within a few years). The fastest throughput rate is limited to the read-out rate of the CCDs – typically 10 MHz today, with peristaltic (buried channel) CCDs promising 1 GHz for the future (ref 4). In addition it is planned to eliminate mechanical changing of the mask by constructing a real-time programmable mask for application to voice processing problems.

REFERENCES

1 Bromley, K., "An Optical Incoherent Correlator," *Optica Acta*, v 21, p 35-41, January 1974

2 Strand, T.C., and Persons, C.E., "Incoherent Optical Correlator for Active Sonar," NELC TR 1887, 27 July 1973

3 Bocker, R.P., "Matrix Multiplication Using Incoherent Optical Techniques," *Applied Optics*, v 13, p 1670-1676, July 1974

4 Anonymous, "And Now – the PCCD," *Electro-Optical Systems Design*, v 6, n 1, p 6, January 1974.

PUBLICATIONS

Bocker, R.P., "Matrix Multiplication Using Incoherent Optical Techniques," *Applied Optics*, v 13, p. 1670–1676, July 1974

Bocker, R.P., Bromley, K., and Monahan, M.A., "Optical Data Processing For Fleet Applications," *Naval Research Reviews*, v XXVII, p 44–48, May-June 1974

Bromley, K., "An Optical Incoherent Correlator," *Optica Acta*, v 21, n 1, p 35–41, January 1974

Bromley, K., Monahan, M.A., and Bocker, R.P., "CCD Performs Scanning in Optical Processor," *Applied Optics* (to be submitted for publication)

Powers, J.P., "Analysis of a Multipurpose Electro-Optical Signal Processor," Naval Postgraduate School Report NPS-52P07411A

Strand, T.C., and Persons, C.E., "Incoherent Optical Correlator for Active Sonar," NELC TR 1887, 27 July 1973

ZR011 12 and ZF61 212
(NELC Z197 and Z274)

Contact
K Bromley
Code 2500
(714) 225-6641

Telecommunication Equipment Low-Cost Acquisition Method [TELCAM]

C. L. Ward

The TELCAM project investigated the feasibility of developing a low-cost acquisition method for telecommunication electronic components, equipments, and systems while at the same time meeting the military performance, availability, and sustainability requirements. In many instances, general specifications are general in nature and tend to produce a product which is "gold plated" for some applications. There are many instances within the military usage of electronic equipments in which commercial products can assume new importance as serious contenders. The TELCAM effort was directed towards providing the project manager with guidance in selecting the best equipment for the operational environment at the lowest overall cost.

The greatest potential for reducing the cost of electronic equipments and systems resides with the decision maker early in the development phase. More cost alert perhaps than in the past, the designer is required to use new approaches to equipment specifications, selection, and development, as well as considering maintenance and support. He is now deemphasizing the acquisition of the highest state-of-the-art and oftentimes unneeded performance in favor of obtaining the best performance for the dollars available. The major part of life-cycle cost is during the operational phase; therefore, serious attention must be given to this aspect. The use of commercial equipments in conjunction with warranties, contractor-supplied services, and spare parts can be an attractive alternate to conventional military electronic procurement and maintenance.

As part of the objective of TELCAM to develop a methodology using appropriate industrial and commercial practices and standards to economically acquire telecommunication equipment, interviews were conducted with many electronic manufacturers of military and commercial products. In addition, Sears & Roebuck, National Steel and Shipbuilding, Todd Shipbuilding, AIRINC, as well as numerous system commands within NAVMAT and Army and Air Force acquisition managers were interviewed. The results of the "Electronics X" program, being conducted by DoD, were analyzed for use on TELCAM. These investigations enabled analysis to be performed of various methods of procuring hardware for industrial and commercial markets. Methods of hardware development, maintenance, and logistics were also studied.

The environmental aspects of hardware were examined to determine the feasibility of reducing criteria levels for specific known applications. Towards the objective commercial off-the-shelf equipment such as memories, plotters, tape recorders, radio-telephones, and closed-circuit television displays were evaluated with promising results. In general, these evaluations supported the concept that commercial equipment, properly designed, would meet certain specific applications for military electronic use with resultant cost savings. In addition, the environmental study also showed that a reduction in environmental criteria was possible for specific applications without decreasing the survivability. Preliminary results for FY74 are documented in NELC TD 335. (See Publication.)

TELCAM is directed toward achieving low-cost electronic equipment and device procurement through the development of alternatives to the use of military specifications. A guidebook which presents ways for managers to develop and procure effective, low-cost telecommunication equipment has been prepared.

The first practical result of TELCAM is a "Guidebook for Development and Procurement of Low-Cost Telecommunication Equipment," an initial draft of which has been prepared for use by NELC program and project managers. The guidebook presents ways for managers to develop and procure effective, low-cost telecommunication equipment through the use of (1) life-cycle cost analyses which consider existing military and commercial equipments as well as new designs; (2) less restrictive environmental characteristics; (3) early planning for maintenance and support; and (4) use of long-term warranties and guarantees integrated with procurement contracts. It is intended that this guidebook be utilized by selected NELC project managers during FY75 and that historical data be collected. The results of this utilization will be incorporated with results of the continuing study to validate procedures. The cost of the hardware development will be borne by the cognizant program office or technical code with engineering support being provided by the TELCAM project. The

TELCAM procurement methodology will be useful for Navy and Tri-Service use for the acquisition of lower-cost electronics.

PUBLICATION

Leffler, R., "Telecommunication Equipment Low-Cost Acquisition Method (TELCAM)" NELC TD 335, 15 July 1974

ZF61.512
(NELC Z269)

Contact:
C.L. Ward
NELC Code 4400
(714) 225-7136

Sponsored Projects Based on IR/IED-Initiated Work

(Only projects not listed in earlier reports*)

Funding	NELC No.	Title	Based on
ELECTROOPTICAL			
1. 62711N WF11.121.710 XF11.121.300	F231	Fiber Optic Cable for Undersea Applications	ZF61.212.001 (NELC Z242)
2. 62721N RF21.242.102	N609	Real-Time Optical Masks	ZF61.212.001 (NELC Z252)
3. 62762N WF54.545.603	F227	Fiber Optics Technology–AIR	ZF61.212.001 (NELC Z246)
4. 62762N XF54.545.022	F225	Fiber Optics Technology–ELEX	ZF61.212.001 (NELC Z246)
5. 62762N XF54.545.033	F233	Blue-Green Dye Laser Technology	ZR011.07 (NELC Z160 and Z198)
6. 63534N S4629	F226	2K-SES Fiber Optic Study	ZF61.212.001 (NELC Z246)
7. 63791N W41X1 [illegible]	F228	A-7 Airborne Lightweight Optical Fiber Technology (ALOFT)	ZF61.212.001 (NELC Z246)
8. O&MN – NAVAIR	F229	Optical Coupler	ZF61.212.001 (NELC Z246)
9. 61153N RR011.07.10	J425	Optical Satellite Communications	ZFXX.212.001 (NELC Z227 and Z275)
ELECTROMAGNETIC PROPAGATION			
1 DNA L25AAXHX635	M220	Magnetospheric Instability Studies	ZR021.01 (NELC Z177)
2. 33109N X3279	M407	SATCOM Space Diversity for Equatorial Scintillation	ZR021.01 (NELC Z192)
3. 61153N RR032.08.01	M221	Ionospheric Irregularity Measurement	ZR021.01 (NELC Z192)
MATERIALS AND PROCESSES			
1 62762N XF54.545.029	R223	Surface Acoustics Wave Device Application in Communication	ZFXX.512 (NELC Z231) ZR021.02 (NELC Z165)
2 [illegible]F (NRL)	F232	Laser Hardened Electrooptical Sensor Electronics	ZR011.07 (NELC Z164 and Z193)
3 62762N RF54.545 003	F302	Indium Phosphide Growth and Evaluation	ZR011.02 (NELC Z193)
4 HDL Army	R218	HDL CMOS Digital Sensor	ZF61 512 (NELC Z262)
5 62762N XF54 545 021	N460	Noise in Charge Coupled Devices (CCDs)	ZR011.02 (NELC Z195)
6 62702E ARPA	N457	Modular Processes for Resolution Restoration (CCID)	ZR011.02 (NELC Z195)
INFORMATION PROCESSING			
1 61153N RR01 40 701	N715	Nonlinear Programming Applications	ZR014.10 (NELC Z166)
2. 6272[illegible]N SF211 70 101	N718	Combat Direction System Processing Architecture	ZR014 02 (NELC Z155)
3 62721N XF21 211 002	N713	Command Center Information System Technologies	ZF61.212 (NELC Z270)
BIOELECTRONICS			
1 O&MN NAV MED CTR	S107	Automated Cardiopulmonary Data System	ZR041.20 (NELC Z182)
2 63706N M4311	S108	Portable Life Support Stretcher	ZR041.01 (NELC Z181)

*NELC TD 141, 1 Sep 1971, TD 194, 1 Sep 1972, and TD 267, 1 Sep 1973

Applications Resulting from Past IR/IED Projects

BIOMEDICAL APPLICATIONS

In FY73 two projects in the biomedical area were funded under 61152N, ZR041.01 and ZR041.20. The work was continued in FY74 with sponsorship by the Naval Medical Research and Development Command, formerly Bureau of Medicine and Surgery, and in cooperation with Naval Medical Center, San Diego (NMCSD), formerly Naval Hospital San Diego. From the combined efforts of physicians, engineers, and scientists, improvements in health care delivery have been made.

Noninvasive Patient Monitoring for Diagnosing Cardiac Pathology

1. An automated data system to provide real-time analysis and interpretation of electrocardiograms (ECGs). Electrodes are attached to NMCSD patients to record ECGs, and the analog data are digitized, recorded on magnetic tape, and, at present, batch processed by the NELC IBM 360/65 computer. A real-time on-line ECG processing system will be located in the Heart Station, Department of Cardiology, NMCSD.

2. Automated computer analysis is made of the ECG, apexcardiogram, phonocardiogram, and the carotid artery pressure tracing, collectively, to derive systolic time intervals. These correlate highly with heart function, and current efforts are directed toward gathering data on prosthetic heart valve patients for long-term evaluation of valve changes.

3. Simultaneous processing of echocardiogram data together with the systolic time interval data has given automated analysis of the left ventricular echocardiogram in limited testing. It has the potential of replacing cardiac catheterization, a surgical procedure, with a noninvasive technique for diagnosing heart disease.

Medical Instrumentation

1. A side-pressure-reading catheter measures squeeze pressure in the sphincter of Oddi in the common bile duct and provides information useful in evaluating pancreatic and biliary disease.

2. A hospital bed scale which gives a continuous display of weight for those patients whose treatment requires a continuous knowledge of fluid balance and who cannot be moved to a conventional scale. A digital display shows the patient's current weight and the total loss or gain during the observation time to within 1 pound.

3. An engineering prototype of a controller for a wheelchair which needs only minimal motion of the patient's head to change the direction or speed of the chair. It enables disabled persons to be independently mobile.

Contact:
J. Silva
NELC Code 3400
(714) 225-6471

FIBER OPTICS TECHNOLOGY AND SYSTEMS DEVELOPMENT

Fiber optics cables in general and the low-loss fiber optics cable in particular promise orders-of-magnitude improvement in bandwidth and increased repeater spacing for long land lines, undersea surveillance, and induced telemetry applications. Immunity from electromagnetic pulse and nuclear radiation effects can also be provided.

In early 1971, anticipating the promise of wide application to the Navy's systems, NELC funded fiber optics technology within the Center's Independent Exploratory Development (IED) Program for theoretical and experimental work.

In succeeding years support with IED funding continued. Meantime, additional sponsored fiber optics projects from various Naval System Commands expanded this work. In FY72 and FY73 the sponsor-funded work in fiber optics exceeded $500k.

The lack of operationally deployable cable is the most important factor limiting the use of fiber optics in military systems. Advancement in the technology of fiber optics connectors, transmitters, and receivers and qualification and standardization of all components are needed to realize maximum impact on military systems. Therefore, during FY74 a large multisponsored program was established to improve

and exploit fiber optics technology through in-house and contract work. The funding provided by NAV-AIR, NAVELEX, NAVSHIPS, ONR, ARPA, and Air Force Cambridge Research Laboratory was expended as shown in table 1, which also includes FY75 plans.

	Technology Development		Systems Development		
	In-House	Contract	In-House	Contract	Total
FY74	$324.5k	$395.0k	$336.0k	$607.0k	$1662.5k
FY75	742.8	527.2	649.0	860.0	2779.0

TABLE 1. EXPENDITURE FOR FIBER OPTICS

FY74 Typical Accomplishments

NELC engineers have produced a repair kit which can be used in the field to repair a severed fiber optic bundle in less than a minute.

Plastic coating of the low-loss fibers is a technology innovation to increase the tensile strength of the larger-diameter fused silica fibers and to increase their bendability. Under a contract, the use of KYNAR has been shown to be very effective

A closed-circuit TV, constructed in FY73, was installed in USS KITTY HAWK and enthusiastically received. It uses fiber optic bundles to carry the video information between a transmitter and receiver which can be separated as much as 1000 feet

FY75 Technology and System Application Objectives

The technology development tasks place emphasis on the basic fiber optic components for developing them to full military-qualified status. This includes the establishment of military standards and specifications for component quality for the fiber optics cables, connectors, T and Star connectors, splicing, and the interface modular devices and circuits. Another major task area is that of component testing and evaluation and tests on radiation effects in sources and detectors. It is hoped that these efforts will lead to a catalog of general-purpose, militarized fiber optic information transmission components within a 3-year period.

To assure Tri-Service coordination and cooperation in the DoD Fiber Optics program, a Coordinating Group of Army, Navy, and Air Force members has been established. This Center will participate actively in coordinating the program arrived at by the Group, which makes recommendations to the Steering Committee.

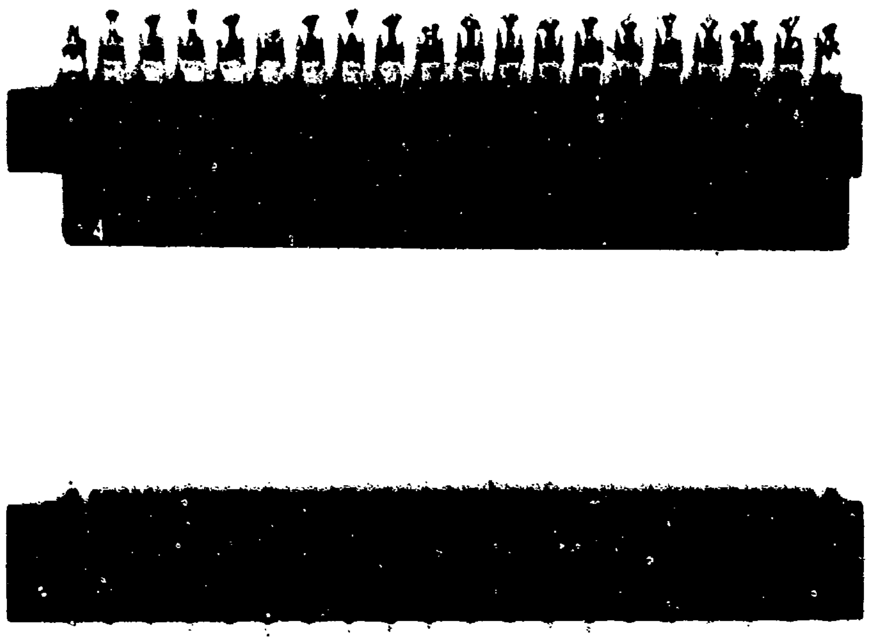
System applications of fiber optics need not wait for the outputs of FY75 technology development. Available fiber optics components can be and are being used today to solve Navy problems and to establish system feasibility and credibility in anticipation of improved fiber optics components promised in the FY75 technology development program. One of the most important system developments in FY75 will be the completion of the design and fabrication of a fiber optic cabling system to replace wires in the navigation and weapons delivering system of the Navy's A-7E aircraft. This will be accomplished by adding time division multiplexing circuits and fiber optics interface circuits externally to the existing avionics and exchanging all the data over fiber optic cables. The demonstration will take place in three stages: laboratory simulation, ground simulation exercising, and full-flight test exercise of the total system.

A joint effort between NELC and Naval Undersea Center (NUC), Hawaii, will result in the development of the Navy's first fiber optics cable for undersea applications. Initially, sample fiber optics bundles and cables will be fabricated to determine the optimum method of incorporating optical fibers into long cables. Then, final cable and electro-optics will be fabricated and tested to meet operational and rigid environmental specifications.

The development under this program will produce a fiber optic cable many kilometers in length (with a goal of 9 km) capable of carrying wide-bandwidth communications signals. This program will provide at the end of FY75 a general foundation for fiber optic cable advanced and engineering development in all Navy undersea areas – FDS, towed arrays, and tether.

Contact:
P. Soltan
NELC Code 220
(714) 225-6702

Modularity and Standardization



C3 Standard Packaging System

X. G. Glavas

A standardized, versatile, modular electronic packaging system that meets existing military standards and specifications and is suitable for full military implementation was developed in this project. This fully documented packaging system enables the circuit design engineer to select the electronic equipment enclosure best suited to his requirements from 28 variations of a basic design in 12 formats. The designs incorporate the extended height Standard Hardware Program (SHP) printed circuit board into selected Air Transport Equipment cases with provisioning for standardized equipment cooling. The system satisfies application environment shock and vibration requirements as substantiated in environmental tests conducted by the NELC Technical and Environmental Evaluation Division (Code 4700).

NELC packaging system enables the circuit design engineer to select the electronic equipment enclosure best suited to his requirements. The system satisfies environmental shock and vibration requirements, and the modular approach is simple and versatile.

Design approaches which satisfy shock, vibration, isolation from radio frequency interference and electromagnetic interference, drip proofing, and ease of maintainability criteria and utilizing natural or forced convection methods of heat transfer were emphasized. Based on thermal load and heat transfer, there are several potential application environments for every packaging system and operational installation. So that the standardized packaging system would be truly versatile, most combinations of packaging density and heat load possibilities were investigated. Electronic equipment enclosure heat transfer capacities and rates were defined in a cooperative effort between NELC Design Engineering Division and the Mechanical Engineering Department at the Naval Postgraduate School, Monterey, California (ref 1).

The results of these tests, which included flow field visualization, isotherm mapping using liquid crystals, and parametric studies of dual in-line package (DIP) resistor network temperatures as functions of power and air flow rate, were utilized in establishing maximum power dissipation capability criteria for devices, glass- and aluminum-core circuit boards, and the application packages of this project.

The modular approach to packaging and cooling described in the "Standard Packaging Designs User's Manual" (ref 2) provides one of the simplest and most versatile modes for packaging Naval electronic shipboard systems for fleet utilization. The packaging system developed in this project eliminates the developmental cost and risk associated with the transition from exploratory development models to production hardware, or any intermediate level. These designs are particularly suited to the envelope philosophy of the CNM Direct Laboratory Funded Project 2175 (two to one improvement in life cycle costs of Naval electronics by 1975) Quick and Easy Design (QED) program, which endorses and extends the Standard Hardware Program. Additional versatility includes compatibility, mechanical and thermal, with the Shipboard Electronics Equipment Modular System (SEEMS). Finally, the system conforms to the electronics packaging philosophy defined for Navy surface effect ships and hydrofoil craft.

REFERENCES

1. Marto, P. J., and Kelleher, M.D., "The Thermal Performance of Air Cooled Circuit Boards used in Standard Electronic Package Designs," Naval Postgraduate School NPS-59Mx74051, May 1974
2. Glavas, X G., and True, R.F., "Standard Packaging Designs User's Manual," NELC TD (in preparation)
3. True, R.F., "Heat Transfer Rates of Printed Circuit Boards used in Standard Packaging Designs," NELC TN (in preparation)

ZF61 212
(NELC Z273)

Contact
X. G. Glavas
NELC Code 4400
(714) 225 7136

VERDIN Demodulator Design Study

G. M. Brechlin

Theoretically, system design would be expedited by the availability of a family of neatly interfacing modules, each performing a common system function. The VERDIN study shows that designing with the NELC-developed QED modules is not only "Quick and Easy" but cost-effective as well.

The VERDIN study was set up to demonstrate the feasibility of a functional design approach using standard building blocks for circuit implementation and determine its advantages. The Quick and Easy Design (QED) Program, which is part of the CNM Direct Laboratory Funded Project 2175 (two to one improvement in life-cycle costs of Naval electronics by 1975), developed a set of QED modules which can be used to build digital signal processors. The demodulator and processor of the VERDIN receive terminal (AN/WRR-7) were selected for comparison with the QED approach because the cost of procuring these items has increased drastically since their development.

Documentation and specifications of the processor and demodulator operation were studied in order to identify the functions which have to be performed to demodulate and decode the received signal and determine the time available to perform these operations in the receive terminal. From this information an all-digital QED design was developed which is functionally equivalent to the VERDIN analog demodulator and digital processor.

A comparison of the estimated properties of the QED with those of the AN/WRR-7 shows that the QED should provide significant reductions in cost, weight, and volume of hardware; simplification of the software needed to perform the decode algorithms; and a reduction in power requirements (see table 1). The cost is cost per unit in quantities of 10 to 50. Further details are classified.

	AN/WRR-7	QED	Ratio QED/ WRR-7
Cost (per unit)	$71k	$31k	44%
Size	3.5 ft^3	2 ft^3	57%
Weight	157 lb	78 lb	50%
Power	200 W	165 W	83%

TABLE 1. PROCESSOR AND DEMODULATOR-POWER SUPPLY UNIT FOR VERDIN RECEIVE TERMINAL, AN/WRR-7 VS QED.

ZF61.212
(NELC Z276)

Contact:
W. J. Dejka
NELC Code 5600
(714) 225-2661

Advanced Digital Communications Modules System [ADCOM]

A.B. Cranmore and G.R. Huckell

A family of reliable, low-cost functional modules that can be used to solve both immediate and future operational telecommunications problems will be the end product of this problem. Advanced information and data processing techniques and advanced modular concepts, supported by the latest microelectronics technology, will be applied in its development.

Existing communications systems and system concepts were reviewed and coordination with ongoing communication automation programs was initiated. From these systems, common functions capable of being individually implemented were identified. These functions were analyzed to determine processing and pheripheral equipment requirements.

Since this project requires that hardware be built, available packaging was scrutinized for suitability. Three possible standards were considered -- the 7½-by-5-inch and the 7½-by-7½-inch modules developed at this Center and the family of Standard Hardware Program (SHP) modules, including the new Super 2A card. The Super 2A card was chosen, as a result of tradeoffs performed in the CNM Direct Laboratory Funded Project 2175 (two to one improvement in life-cycle costs in Naval electronics by 1975) Quick and Easy Design program. Modifications were made in the form of new artwork to facilitate use and provide added flexibility.

As a result of the recent development of the microprocessor, direct functional implementation of communication requirements is now possible. A survey of existing microprocessors was conducted and a decision was made to base present exploratory efforts on the Intel 8080. Support electronics for the Intel 8080 will be the Intel 2102 static random-access memory chip and the Intel 1702A erasable read-only memory chip.

Advanced communication systems cannot be built without peripheral equipments such as printers, keyboard, displays, and memories. A cursory survey of presently available peripheral technologies revealed that many good commercial peripherals exist, but the problems of selection and militarization will have to be solved.

Advanced technology is incorporated in a family of modules designed for wide application in telecommunications systems.

On the basis of experience gained by the surveys of communication functions, packaging, microelectronics technology, and peripherals, the Submarine Satellite Information Exchange System (SSIXS) subscriber terminal was chosen for implementation. It is a good vehicle for ADCOM because it does not require development of peripheral equipment, can be demonstrated in a short time period, and is capable of high pay-off. Currently, the SSIXS subscriber electronics consist of the WSC-3 transceiver, a UYK-20 central processor, a junction box containing link control logic, and a magnetic tape unit for UYK-20 software loading. If implemented, the ADCOM SSIXS subscriber functional module would perform the functions of the UYK-20 and eliminate the requirement for the magnetic tape unit.

Advantages of the proposed SSIXS functional module over the present terminal are much smaller size (which is important in a submarine environment), lower power consumption, lower cost, and higher reliability. In addition, two terminals could be installed in the submarine in one fifth the space occupied by the present subscriber terminal, providing 100% redundancy

To date, the major hardware portion -- consisting of the central processing unit and memory -- has been designed and tested. Portions of the firmware that will not be adversely affected by system changes have been flow-charted and coded in a symbolic assembly language, developed under ADCOM, that is compatible with an existing compiler (CS-1).

ZF61.212
(NELC Z272)

Contact:
A. B. Cranmore
NELC Code 3200
(714) 225-6807

Atmospheric Propagation

Equatorial Scintillation Research

V. E. Hildebrand

Initial tests of a fleet satellite communications system showed that severe disruption of service was often experienced during the nighttime in equatorial regions. Directed tests by NELC personnel during the spring periods of 1970, 1971, and 1972 determined that the satellite signals traversing the equatorial ionosphere often exhibit severe scintillations with fluctuations up to 25 dB in amplitude. The Navy has been committed to a uhf satellite system for future fleet communications and must live with this problem; thus, this project was initiated to determine what can be done to minimize the impact of scintillations on Navy systems.

The Navy is fully committed to a uhf satellite system for future fleet communications. During tests strong scintillation has been found to degrade system performance. This project was initiated to determine what can be done to minimize the disruptive effect of scintillation exhibited by satellite signals traversing the equatorial ionosphere. Several avenues have been investigated by which needed information can be obtained which have resulted in several proposals for further work, some of which have been approved and separately funded.

An extensive literature survey and contacts with various workers in the field provided the basis to evaluate the current state of our knowledge on scintillation phenomena. The survey showed that scintillation activity is a worldwide phenomenon having greatest severity in the equatorial and polar regions. The general consensus is that scintillations are caused by irregularities in ionization density in the F-region of the ionosphere, but the possibility that they occur at greater altitudes has not been thoroughly explored. In addition, a thorough morphological description of the boundaries, longitudinal asymmetries, and solar cycle behavior of the various scintillation regions does not exist. The greatest deficiency in our knowledge of scintillation phenomena is the identification and description of the mechanism which causes irregularities to form in an otherwise very smooth ionization distribution in the ionosphere. Several speculative theories have been proposed, but these lack definitive testing because detailed knowledge of the structure of the irregularities is also unknown.

Several tasks were subsequently undertaken to pursue avenues by which the lacking information can be obtained. The tasks were:

- Study of means for characterization of the scintillation channel in terms of the impulse response or transfer function;

- Examination of the usefulness of satellite experiments currently in operation and planned to be flown in the immediate future for measurement of solar and geophysical phenomena related to scintillation irregularity research;

- Use of holographic techniques at radio wavelengths to determine the detailed structure of the irregularities; and

- Examination of the effects of irregularities in the outer plasmasphere on transionospheric radio wave propagation.

Phase measurements on the scintillation channel are lacking and deserve high priority in future experimental research. This will provide much-needed information for communications designers as well as settle doubts about whether theoretical work should address strong or weak scattering.

The satellite experiments task showed that essentially much of the information pertinent to irregularity research is currently being obtained. A new series of satellites, the Atmospheric Explorer series, has been initiated which should provide valuable measurements provided these are supported by proper ground-based measurements. In addition, recent measurements by satellites traversing the plasmapause showed extensive structure about this boundary which could result in significant scintillations of geostationary satellite signals.

The ionospheric holography task was undertaken to develop a new technique for the three-dimensional reconstruction of the ionospheric spatial irregularities responsible for scintillations in transionospherically propagated radio signals. It is based on applying the well developed techniques of optical holography at meter and shorter wavelengths.

The outer plasmasphere task examined propagation through a particular type of irregularity which was proposed to support whistler ducting propagation. The influences of this irregularity structure were found to be important only at hf unless exceptionally large density variations are present.

These tasks have resulted in several proposals for ongoing work to make definitive measurements which will aid in minimizing the impact of scintillations upon Navy systems and provide the concise information needed for further theoretical development on source mechanisms.

PUBLICATIONS

Hopkins, R.U.F., and Paulson, M.R., "Equatorial Scintillation," NELC special edition of *Naval Research Reviews*, v XXVII, p 17--24, May-June 1974

LaBahn, R.W., "Recent Experiments Exploring the Properties of F-Region Irregularities that Give Rise to Spread-F and Scintillations," NELC TR 1896, 11 October 1973

Paulson, M.R., "Status of Scintillation and Spread-F Research," NELC TN 2669, 22 April 1974

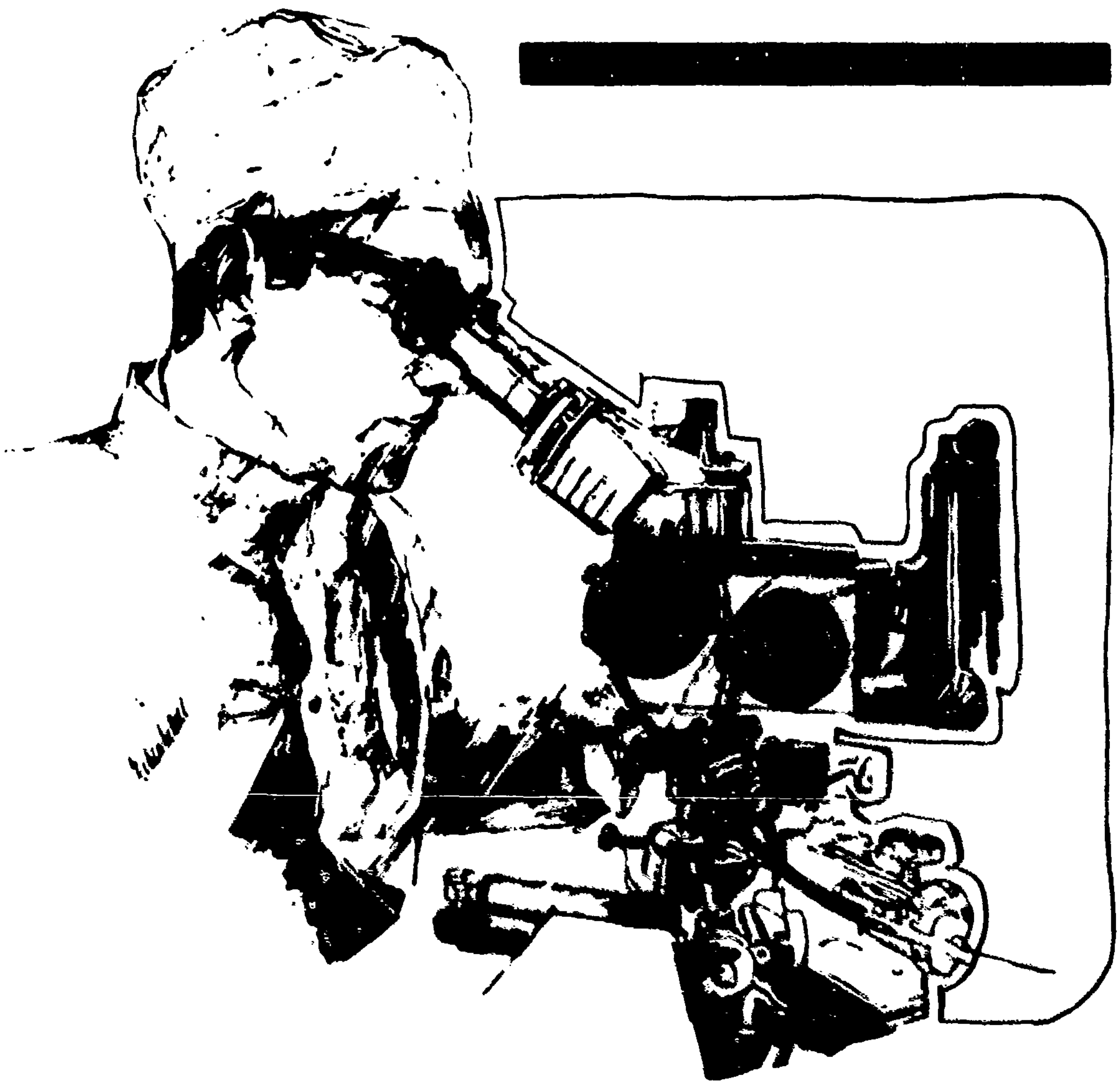
Major, R.W., "Consideration of World-Wide Scintillation Prediction Techniques, NELC TN 2501, 18 October 1973

Major, R.W., "A Compendium of Satellites for Atmospheric, Ionospheric and Magnetospheric Research," NELC TN 2564, 19 December 1973

ZR021.03
(NELC Z192)

Contact:
V. E. Hildebrand
NELC Code 2200
(714) 225-7919

Electronic Materials and Devices



Preceding page blank

Devices for New Frequency Regions

INTRODUCTION

J. W. Carson

The three following articles (shf/ehf Solid-State Amplifiers, Warm-Carrier Thermoelectric Effect, and Terahertz Technology) and one of the Highlight articles (ehf Integrated Circuits) report the results of an interdivisional effort combining talents in materials research and microwave engineering to develop devices for the ehf/shf and infrared bands in support of surveillance and communication systems currently in development at NELC. These systems represent the beginning of what is expected to be a period of greatly intensified Navy use of the interval from 20 to 100 GHz and the IR region.

Devices for New Frequency Regions:

shf/ehf Solid-State Amplifiers

D. L. Lile and D. Rubin

The Navy has an immediate requirement for low-noise, wideband amplifiers for shf and ehf receivers. High reliability, performance, and the potential for low cost are important considerations for these amplifiers; in addition, small size is a critical factor for some receiver systems. Recent advances in two types of solid-state amplifiers, the field effect transistor (FET) and transferred electron amplifier (TEA), suggest that they may eventually provide the above-mentioned capabilities. Because of NELC's commitment to the advancement of rec ... r technology, an investigation was undertaken on some aspects of the current R&D problems of FETs and TEAs

The program began with a materials review of InP in the last quarter of FY73. The program was extended in FY74 to materials studies, device fabrication, and circuit investigation.

The materials studies were directed at investigating $InAs_xP_{1-x}$ for three reasons: (1) very low noise performance had been reported for an InP TEA at 33 GHz in England, (2) material for InP diode fabrication was not available in the United States, and (3) the high value of mobility of InAs suggested that $InAs_xP_{1-x}$ might lead to higher-frequency FETs than presently possible with GaAs, the current standard material.

After consideration of crystal growing methods, liquid phase epitaxy (LPE) was chosen. Fine control of temperature and temperature uniformity were considered necessary to obtain quality epitaxial crystals, so a system was designed which included a furnace arrangement for an isothermal environment and a programmable temperature controller that regulated temperature to about ±1/50°C. The system was assembled in the third quarter and a number of crystals were grown in the last quarter. InP and InAsP were grown on GaAs and InP substrates. The epitaxial crystals, typically about 10 μm thick, were of good quality. Thinner layers, more suitable for devices, are feasible with this system. The liquid phase epitaxy system will be used in an ONR sponsored program (NELC F302) on InP in FY75.

Available space is usually a constraint in the design of receiver systems for use aboard ship, and it is especially severe for the areas in which antennas must be installed. Associated amplifiers and other electronic equipment of conventional dimensions must frequently be located remotely, sometimes at a sacrifice in system performance.

A critical Navy requirement brought about by this problem is the development of a solid-state amplifier for shf and ehf receivers. Contributions to this development were made at this Center in the areas of materials study, device fabrication, and circuit investigation.

Along with the convenience of small size, the solid-state amplifier is expected to provide cost and performance advantages in future Navy surveillance and communication systems.

Since InAsP materials were not immediately available, device fabrication began with commercial and in-house-prepared GaAs. Both FETs and TE diodes were fabricated and tested.

The FET devices had a Schottky barrier gate electrode. The approach was to investigate and develop, in house, FET fabrication procedures to the extent that this was feasible in a limited-effort program. A procedure was developed and several devices were built. The FETs had the desired dc characteristics but did not display gain in the microwave region. Possible reasons are large source-drain spacing (8 μm, imposed by the available photomask) and large contact pads which effectively introduce excess capacitance. Neither is considered a fundamental limitation, and both could be relatively easily handled in any subsequent program.

TE diodes were built and operated as Gunn oscillators and amplifiers around 10 GHz. In the amplifier work, reflection gains of about 10 dB were observed for pulsed signals; insufficient thermal heat sinking precluded cw operation.

The circuit investigation started with commercial FETs and TE diodes. The immediate objective was to develop wideband circuits with these devices and the ultimate goal was to use the designs with lower noise devices when available.

Computer programs were devised for FETS that (1) correct data for FETs obtained with a nonauto-

matic network analyzer, (2) use the corrected data to calculate gain and stability parameters of FETs as a function of frequency, and (3) select impedance-matching circuits suitable for specified gain-bandwidth characteristics. A single-stage FET amplifier which was built at 6 GHz according to this analysis performed as calculated, thus confirming the validity of the analysis and showing its utility.

TEA circuits were investigated at 26-40 GHz. Reflection gains of 15 dB with a 2.5-GHz bandwidth and 6 dB with a 7.5-GHz bandwidth were obtained by external positioning of the diode and short. The $(\text{gain})^{1/2}$-bandwidth product is as high as the best published results. An extensive measurement program was undertaken at 26-40 GHz to determine the diode admittance vs frequency. Computer programs were written to analyze the data and to optimize amplifier circuit performance. The methods used to determine diode characteristics will be applicable to other ehf devices. The work is believed to be an important contribution to the design of ehf amplifiers.

PUBLICATION

Rubin, D., "Measurement of Gunn Diode Parameters at Millimeter Wave Frequencies," *IEEE Transactions on Microwave Theory and Techniques* (submitted for publication)

ZR011.07
(NELC Z193)

Contact:
J. W. Carson, D. L. Lile, or D. Rubin
NELC Codes 2300 and 2600
(714) 225-6763, 225-6591, or 225-7097

Devices for New Frequency Regions:

Warm-Carrier Thermoelectric Effect

A. Nedoluha

Improved ehf detectors are needed for Navy surveillance receivers under development. In this analytical program, an elementary analysis was carried out on the warm-carrier thermoelectric effect (WCTE) to determine its potential for mm-wavelength application and to provide guidance in later experimental work. Detection occurs in the WCTE as a result of the nonuniform heating of majority carriers by a spatially nonuniform rf electric field. Although this is generally accomplished in the vicinity of a point contact, detection by junction barrier action is not involved. The WCTE was investigated in Si and Ge about 10 years ago in the United States, but the investigation was discontinued, apparently for lack of interest in ehf detectors. The only recent reported work has been from the Soviet Union.

Results of calculations indicated that n-type indium arsenide (InAs) should be a better material for warm-carrier thermoelectric effect detectors than previously used silicon and germanium. An InAs diode was made, and preliminary measurements are encouraging.

An elementary theory of the WCTE was developed for Si, Ge, and n-type InAs. The responsivity and noise equivalent power were calculated for these materials. The responsivity (ratio of output I or V to input power) was found to increase with increasing carrier mobility and energy relaxation time and with decreasing carrier concentration and contact radius. On the basis of these results, it appears that n-type InAs should be a better material than the previously used Ge and Si. An InAs diode was made and preliminary measurements were taken. The current responsivity was found to be comparable to that reported for Ge but much less than calculated. This is encouraging for a first attempt in which material and fabrication were far from optimum.

The present understanding of WCTE detectors is that (1) the upper frequency limit should be in the sub-mm region, (2) responsivity is high, (3) resistance to burn-out is large, and (4) 1/f noise should be negligible. This combination of characteristics makes the WCTE attractive for wideband detector and mixer use in the mm band. A continuation of the WCTE investigation is therefore desirable. Future efforts should include device fabrication and measurement, development of an improved theory, and investigation analytically and experimentally of a possible magnetophonon WCTE which might enhance detector responsivity.

ZR011.07
(NELC Z193)

Contact:
J. W. Carson or A. Nedoluha
NELC Codes 2300 and 2600
(714) 225-6763 or 225-6591

Devices for New Frequency Regions:

Terahertz Technology

S. A. Miller

The Terahertz Technology program has been concerned with the investigation and development of a continuously tunable infrared (IR) laser and an inexpensive coherent IR mixer. The components have great potential value in IR laser communication systems. The tunable IR laser would provide these systems with new capabilities such as transmitter frequency agility for resistance to EW and rapid frequency adjustment for the utilization of atmospheric absorption. It could also be used as a wideband, electrically controlled local oscillator in receivers. An inexpensive, sensitive, room-temperature IR mixer would be an important factor in the application of IR communications systems.

A spin-flip Raman laser (SFRL) is under development to provide continuously tunable IR radiation. In this laser, a recent development, a fixed-frequency pump laser is used to stimulate Raman radiation in a semiconductor resonator. The frequency of the Raman radiation is a function of the magnetic field applied to the semiconductor, so electrical control of the magnetic field provides rapid and direct control of the frequency of the Raman radiation. The SFRL program started in FY72 when the basic equipment -- chiefly the pump laser and superconducting magnet -- was obtained and assembled. Data were obtained from SFRL operation in FY73.

Communications technology is moving into the terahertz (= 10^{12} hertz) frequency or infrared range with a variety of laser transmission links under test and on drawing boards. Improved laser transmitters featuring wide tunability and sensitive room-temperature wideband mixers promise to provide future systems with greatly enhanced capability.

Effort in FY74 was directed at improving operation at 5 μm (60 THz) and extending operation to the 10-μm (30 THz) region. The optical pumping system was analyzed, and a redesign applicable at both 5 and 10 μm was completed that increased the pump irradiance by about a factor of 20. As a result the efficiency of energy conversion to Raman radiation was correspondingly increased. An additional improvement in efficiency of energy conversion was achieved with the development of a new cavity arrangement of the Raman sample. The resonator walls and reflective coatings are arranged in a manner such that the pump beam is optimally focused in the Raman sample and the stimulated Raman radiation output is maximized. The optical configuration is similar to that of a Cassegrainian system. An invention disclosure was submitted for this device.

SFRL investigations were planned for 10 μm, and the initial design was performed. Specifications were prepared for the purchase of a highly stable, single-mode 10.6-μm laser for use as the Raman pump source.

A new area of investigation was the metal-oxide-metal (M-O-M) mixer. This device consists of a point contact between two metals with a thin oxide layer at the contact. It functions as an IR mixer with the output signal extending from the rf up into the sub-mm region. This device is of special interest because of its inherent simplicity and potential low cost. Successful mixing requires a very fine point and a precision adjustment mechanism for making the contact. A procedure was developed for making the points (typically 1000-Å radius). The mixer device showed a nonlinear I-V characteristic, but mixing was not observed. It is believed that the main problem was instability of the contact, which is being corrected with a more rugged mount.

On the basis of information gained from the present SFRL system, which was designed for laboratory work and is large, a small prototype unit is now feasible. Construction and evaluation are recommended to assess the impact of the SFRL on IR communications.

ZR011.7
(NELC Z193)

Contact:
J. W. Carson or S. A. Miller
NELC Codes 2300 and 2600
(714) 225-6763 or 225-6591

Solid-State Materials and Processes Characteristics

INTRODUCTION

C. E. Holland

The following four articles describe work performed during FY74 under NELC Z195. The major thrust of this program is toward the research and development of advanced techniques and capabilities at NELC for the scientific analysis, understanding, and control of semiconductor materials and devices important for advanced Navy systems.

The program is cooperative in nature, involving several distinct groups in two NELC departments, industrial and academic concerns, and interaction with the Naval Research Laboratory.

A number of discoveries applicable to device quality and reliability improvement have germinated in this program during FY74. Additional work to carry these developments through to fruition is planned for FY75.

Solid-State Materials and Processes Characteristics:

Semiconductor Profiling With an Optical Probe

D. L. Lile and N. M. Davis

This project is specifically directed to the improvement of device reliability through the correlation of physical and chemical microinhomogeneities in silicon with device electrical properties. The use of a small spot of light for the detection of semiconductor inhomogeneities is described. Although the results presented are for device-grade n-type Si, similar results have been obtained on other materials, such as GaAs and InAs, and in fact the method should be applicable to any semiconductor in which a surface depletion layer can be generated.

The method developed by this investigation employs a scanned measurement of the surface photovoltage generated in the surface space charge region of the semiconductor to detect defects in silicon. Metal-oxide-semiconductor (MOS), Schottky barrier, and electrolyte contacts may be used to sense the signals. Furthermore, it is possible to monitor the variation of carrier lifetime across the area of the sample from a spectral measurement. The results suggest that this technique offers a possible noncontacting procedure for the characterization of sample homogeneity.

Whenever excess carriers are injected into a region of semiconductor in which there exists an electric field, a separation of carriers occurs resulting in a modification of the electric field and the generation of a photovoltage. When the electric field occurs at the surface of a semiconductor, the resulting voltage is termed the surface photovoltage, and appears as a change in potential between the surface and the bulk of the sample.

When a semiconductor sample is uniformly illuminated, the surface photovoltage is generated over the entire surface of the sample. However, if a spot of light much smaller than the sample area impinges on the surface, then carriers are generated in a region of diameter equal to that of the light spot and of approximate depth into the sample α^{-1}. These generated carriers diffuse a distance L_D (Debye length) beyond the boundaries of the generation region.

The surface photovoltage, proportional to the excess carrier density at the surface, then follows the intensity profile of the light beam within the beam and decays approximately exponentially in L_D away from it.

To measure the surface photovoltage, an apparatus was assembled as shown in figure 1. Electrical contact is made both to the bulk of the sample and to the surface via an electrolytic solution.

Except as noted, all the results reported here were obtained at ambient room temperature on <100> oriented slices of device-grade n-type silicon of resistivity in the range 1-3Ω cm. The slices were 500 μm thick, with a mirror polish on the front surface and a lightly etched saw cut finish on the back. Some of the samples were coated with a wet thermal oxide layer approximately 1 μm thick. Schottky diodes and MOS devices were prepared by thermally evaporating Ni through aperture masks onto the surfaces of the samples. Semitransparent electrodes were made by restricting the Ni thickness to approximately 150 Å.

To illustrate some of the concepts outlined above, figure 2 shows the surface photovoltage generated by a single-line scan of a 10.0-μm diameter spot across a 400-μm diameter semitransparent Schottky barrier. The approximately exponential rise of the signal as the spot approaches the electrode and the sharp reduction as the spot moves onto the electrode are apparent.

As well as providing a qualitative display of such structures, it is also possible to make a quantitative measurement of minority carrier lifetime in these devices. Figure 3 shows the results of a spectral measurement made by positioning the light spot (<10-μm diameter) between the electrodes of a transistor. Although we do not have an independent measurement of the lifetime in the material from which the device was constructed, the data in figure 3 are linear over a very wide spectral range in agreement with theory and indicate a diffusion length for this material of approximately 39.0 μm.

The results of this investigation have shown that microinhomogeneities in semiconductors may be detected by means of an optical probe and further that a quantitative assessment of the magnitude of the inhomogeneity may be made through a measurement of carrier lifetime. It is anticipated that this technique will allow defects to be identified early in the pro-

duction cycle of semiconductor devices and ICs and hence lead to increased yield and reliability of semiconductor circuits.

ZR011.02
(NELC Z195)

Contact:
C. E. Holland, Jr., D. L. Lile, or N. M. Davis
NELC Codes 4300 and 2600
(714) 225,6860 or 225-6591

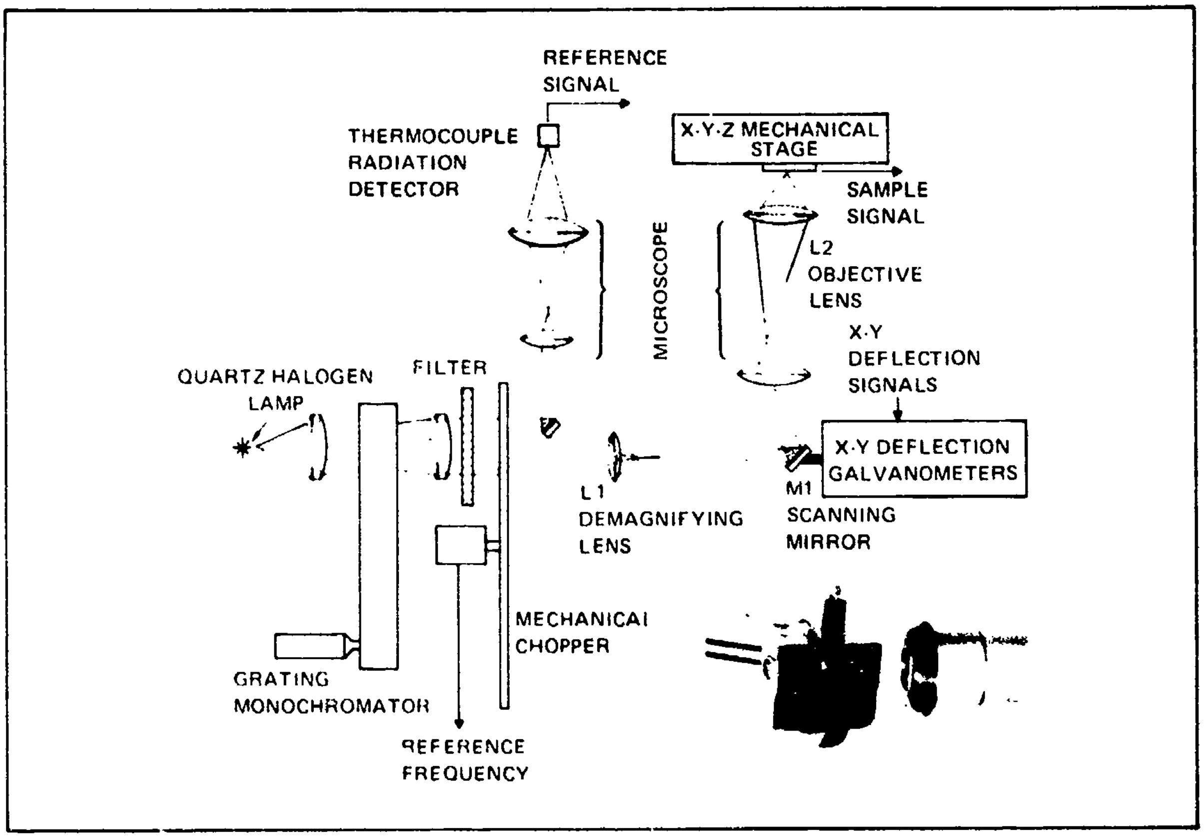


Figure 1. Schematic of scanning light probe system. Insert shows details of scanning mirror galvanometers.

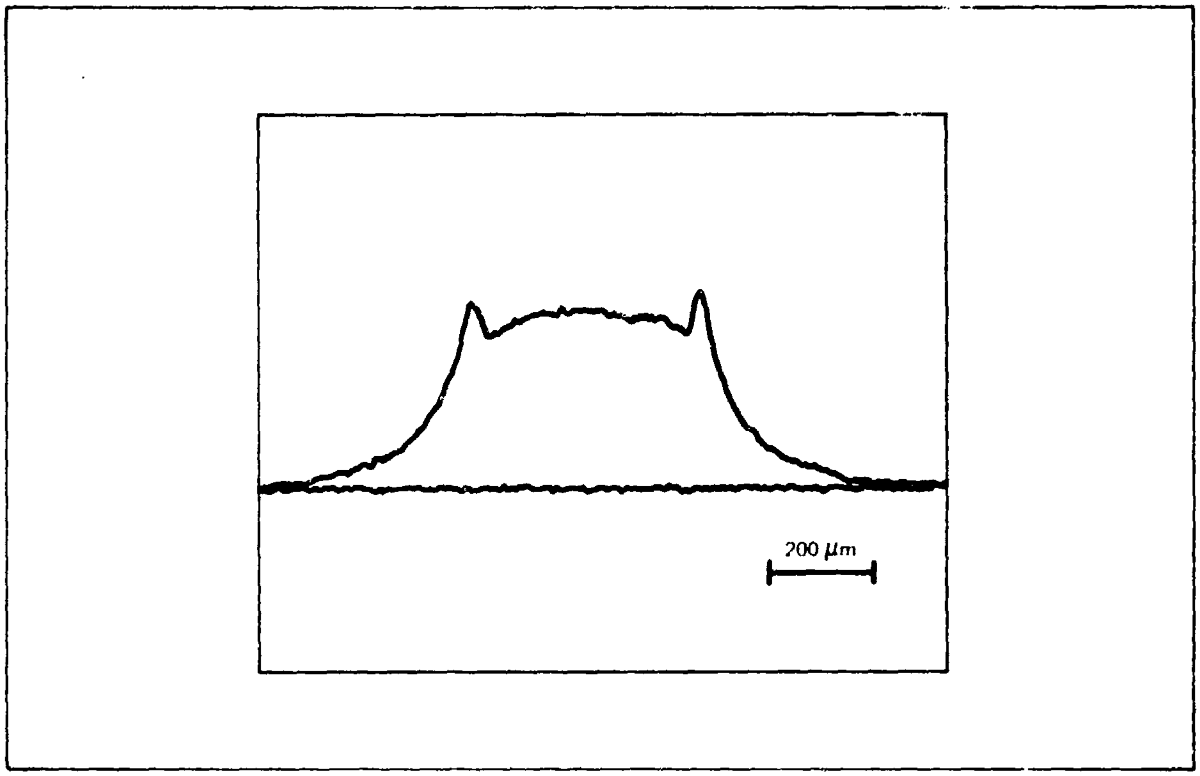


Figure 2. Surface photovoltage response for a single line scan of a 10-μm diameter light spot of 1.0-μm wavelength across a semitransparent electrode Ni/Si Schottky diode. The horizontal line is the zero reference.

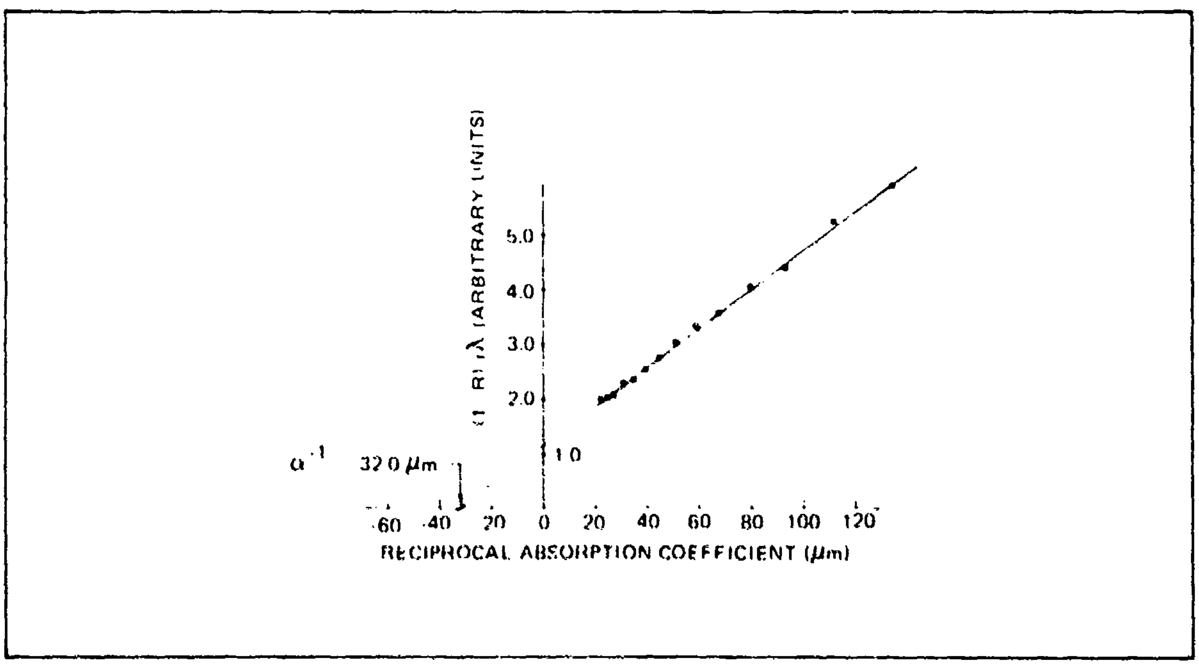


Figure 3. Spectral photovoltage data with a 10-μm diameter light spot on a Si MOS device.

Solid-State Materials and Processes Characteristics:

Semiconductor Reliability Improvement by Process Control and Surface Analysis

M. E. Aklufi and N. K. Wagner

Large Scale Integration (LSI) devices are increasing in complexity and sophistication. For their potential benefits to be realized in Navy systems, the materials and processes which determine quality and reliability must be understood and controlled. During FY74, an analytical capability to conduct in-depth semiconductor diagnostic investigations was established. This capability was complemented by the development of a comprehensive test structure to provide the electrical data necessary to relate complementary metal-oxide-semiconductor (CMOS) materials and process parameters to device physical and operational characteristics.

A diagnostic capability was implemented at NELC in FY74 and applied to MOS LSI processing, hybrid integrated circuits, assembly operations, and failure analysis. A number of specialized methods were applied.

AUGER ELECTRON SPECTROSCOPY (AES)

The elemental composition of the surface of integrated circuit devices was determined by AES at key points in MOS/LSI, hybrid integrated circuits, and assembly operations. The presence of unsuspected impurities was determined. The impurities were generally segregated within the first few mono layers (approximately 30 Å) of the solid surface and were therefore detectable only by a surface-sensitive technique. Sources identified for these impurities include processing residuals (chlorine, sulfur), cleaning chemicals (fluorine), and contamination (sodium, iodine, silver). The effect of these impurities on device characteristics is presently under study

X-RAY TOPOGRAPHY

X ray transmission topographs were performed of starting and processed silicon wafers. Relatively fine crystal defect structure was found on all starting wafers independent of vendor, showing the effect of polishing and handling. Although these are generation regions for dislocation networks, massive networks were noted only after high-temperature processing steps and only in highly stressed areas where sharp thermal gradients existed. The effects of these dislocations statistically correlated best with leakage currents measured near the source-drain breakdown regions of N-channel MOS (NMOS) test transistors. Mechanisms for these effects have been postulated.

SCANNING ELECTRON MICROSCOPY (SEM)

SEM has been used to evaluate which process procedures provide the best metal oxide slope coverage in the baseline process. Improved slope coverage is consistently obtained when oxide slopes are defined during the oxide etching step of the photolithography process.

Utilizing the SEM in the voltage contrast mode has proved effective in easily displaying and identifying where LSI failure modes are located on a given circuit. The intermittency of an MOS LSI enhancement type read only memory was traced to an NMOS transistor that was operating incorrectly in a near-depletion mode. This deviation has been attributed to an inhomogeneity causing an increase in the sheet resistivity of the transistor's channel region.

ELECTRON SPECTROSCOPY FOR CHEMICAL ANALYSIS (ESCA)

ESCA services are being used to further identify contamination sources by determining the chemical compound structure of surface impurities detected by Auger analysis.

SECONDARY ION MASS SPECTROMETRY (SIMS)

The SIMS technique is being evaluated for characterization impurity profiles.

TEST PROGRAM FOR AVAILABLE TEST PATTERNS

To aid in the rapid accumulation of electrical test data, a test program has been generated for existing test patterns on a Fairchild Sentry 600 LSI tester. Printouts of the data include device parameter, mean, and one-sigma deviation values. To analytically evaluate the data in terms of physical parameters, device modeling programs have been generated on an IBM 360 computer. An interface program between the Fairchild 600 and the IBM 360 has been established.

The baseline CMOS aluminum gate process has been evaluated with the available test patterns. Results, including electrical and physical parameters, have defined the baseline process.

CUSTOM TEST PATTERNS

Advanced test patterns that relate the CMOS baseline process to discrete devices as found in LSI circuits, modeled devices, and special devices were designed. In all, some 50 devices were designed, including over 10 state-of-the-art test patterns. Rubylith pattern layouts and iron oxide processing masks have been fabricated. Stack-up of the test patterns in the LSI processing laboratory has been completed.

OTHER FY74 EFFORTS AND FINDINGS

Measured effects of electron beam radiation on MOS capacitors include an increase of fast interface states with increasing dosage and energy of impinging E-beams. These states can be removed by heating, which indicates a time-temperature relationship. Flatband voltage shifts not seen prior to radiation have been noticed after heating, suggesting the presence of carrier trapping sites.

Techniques were developed to fabricate optically transparent aluminum electrodes for MOS capacitors and optically transparent titanium-platinum electrodes for near-ideal platinum-silicide Schottky barrier diodes. These devices were fabricated in the LSI laboratory for use in photo-voltage scanning experiments.

Existing test patterns were mounted in 16 dual-in-line ceramic packages (unlidded) and were subjected to an accelerated temperature life test at 125°C. Source-drain leakage currents of both the P-channel MOS (PMOS) and NMOS transistor types were found to be the most sensitive life test monitoring parameters. Excessive leakages were noted after 7 hours of life test for NMOS transistors without protective oxide, whereas only 25% of the transistors with protective oxide, irrespective of type, had excessive leakages after 1000 hours. Assuming ion drift and interfacial trapping mechanisms with an activation energy of 1.0 eV, the 1000 hours of accelerated life test at 125°C can be extrapolated to mean a life of 5.0 years at 85°C.

ZR011.02
(NELC Z195)

Contact:
C. E. Holland, M. E. Aklufi, or N. K. Wagner
NELC Codes 4300 and 4800
(714) 225-6860 or 225-6877

Solid-State Materials and Processes Characteristics:

Spatial Homogeneity of III-V Compound Semiconductors

H. H. Wieder, N. M. Davis, and D. L. Lile

The objective of this task is the investigation of the spatial homogeneity of intermetallic semiconducting III-V compound bulk crystalline and epitaxial layers. Electron beam and optical scanning surface photovoltage measurements are the means by which correlation with the operational characteristics of diodes, transistors, and light-emitting diodes (LEDs) is determined.

The investigation is motivated by the promise that performance and reliability of Naval communication and surveillance systems can be improved considerably by the use of the intermetallic III-V semiconducting compounds for the construction of high-frequency, high-power, and high-efficiency discrete and integrated electronic components and circuits.

The spatial homogeneity of the direct energy bandgap semiconducting compounds gallium arsenide (GaAs), indium arsenide (InAs), indium antimonide (InSb), and indium phosphide (InP) was examined by means of the following different diagnostic methods:

- By the interaction of a scanning electron beam incident on and penetrating the specimen to a depth of approximately four charge carrier diffusion lengths. The localized IR radiation emitted by the radiative recombination of electron-hole pairs produced by the raster scanned electron beam forms a pseudo topographic map of the free-carrier distribution across the specimen. Lifetime and diffusion length of minority carriers in Schottky barrier and pn junction test structures are determined by measuring the distance away from the junction at which the current induced by the electron beam decreases to 1/e of its value at the junction.
- By means of scanned photovoltage measurements used to determine the spatial distribution of the minority charge carrier lifetimes in both bulk and epitaxial layers and their dependence on the chemical impurity distribution and crystalline lattice defects

Spatial resolution of 10 μm is achieved with the scanning cathodoluminescence system which has been used for investigating the spatial homogeneity of radiative combination from GaAs light-emitting diodes. The direct correspondence between injection electroluminescence emission and cathodoluminescence emission was established, and a correlation between fluctuation in impurity concentration on each side of the metallurgical junction plane and the corresponding variation in cathodoluminescent efficiency was determined. The spacing between the emission peaks on each side of the junction plane and the emission minimum at the metallurgical interface are correlated with the external quantum efficiency of the LED.

This program is directed to the development of techniques to enable a correlation to be made between material properties and device performance. Particular attention is directed to the III-V compounds because of their inherent promise of improved device performance in Navy communication, surveillance, and other systems.

The scanning electron beam system has been used to determine the diffusion length in IC-grade silicon for confirmation of results obtained by scanned light methods.

The major effort for the first half of the FY74 program was the design and construction of a scanning light beam probing system and the installation and modification of a scanning electron microscope for IR cathodoluminescence studies.

In addition, the spatial homogeneity of an InSb 10-element IR detector array was determined by means of the scanning optical system capable of detecting photovoltage nonuniformities. It was determined that the spread in device response is typically ±15% about the mean, and that the scanning system lends itself for determining the homogeneity of IR detector arrays operating as far into the IR as the 3-5-μm region.

This system is capable of operation over a wide spectral range and thus is equally applicable to the III-V compound semiconductors and elemental silicon.

The scanned optical and electron beam (cathodoluminescence) techniques which have been developed have been shown to yield information on the properties of III-V compounds and devices fabricated from these materials. The correlation of these prop-

erties offers the prospect of improved control in manufacturing of semiconductor circuits with resultant benefits to the Navy in increased reliability of components.

PUBLICATIONS

Davis, N.M., and Wieder, H.H., "Infrared Scanning Cathodoluminescence Apparatus and Applications," *IEEE-IAS Conference Record*, Milwaukee, Wisconsin, October 11, 1973.

Lile, D.L., and Davis, N.M., "Photovoltaic InSb MOS Array," Infrared Information Symposium, El Toro Meeting, March 1974

Lile, D.L., and Davis, N.M., "Semiconductor Profiling using an Optical Probe," August 1974 (to be submitted for publication)

Wieder, H.H., "Transport Coefficients of InAs Epilayers," *Applied Physics Letters*, August 15, 1974 [in press]

ZR011.02
(NELC Z195)

Contact:
C.E. Holland, Jr., H.H. Wieder, N.M. Davis, or D. L. Lile
NELC Codes 4300 and 2600
(714) 225-6860 or 225-6591

Solid-State Materials and Processes Characteristics:

Noise and Optical Measurement Techniques for CCIDs

C. R. Zeisse

In an investigation of the suitability of charge coupled devices for use in low-light-level imaging systems, what appears to be the best method yet devised for measuring transfer efficiency has been developed.

The charge coupled imaging device (CCID) is a new silicon solid state optical sensor, the characteristics of which are not yet precisely known. It stores optical information in discrete packets of electronic charge varying from a single electron to as many as a million electrons. The packets are stored underneath silicon capacitors in "wells," and shifted from well to well to an output amplifier when the stored information is required.

This program was set up to measure the actual low light-level performance of the CCID, specifically its signal and noise characteristics. Signal measurement required the elimination of spatial frequency ambiguity, and noise measurement required the elimination from the recording of the disturbing effects of the large amplitude clocking waveform. Band limited optical test patterns met the first requirement and a digital sampling system was developed to meet the second.

The manner in which the frequency response is measured at NELC is shown in figure 1. This technique has been used on a 500X1 linear CCID array, and the results are shown in figure 2. To the best of our knowledge, these are the first results to show agreement with theory. Furthermore, this method may provide a more sensitive measurement of transfer efficiency than any previously available.

A second objective was to measure the noise of CCID arrays as a function of temperature. This information can be used to determine the predominant noise mechanism by comparing the measured results with various noise models pertinent to CCIDs. The difficulty of the task can be appreciated by noting that the presence of 10 electrons on an output capacitor of 0.1 pF would lead to a voltage on the order of 10 microvolts which must be sensed in the presence of clock feedthrough transients on the order of 1 volt.

A digital system was developed capable of measuring a noise of several hundred electrons per picture element, adequate for the 500X1 array. The system was later improved by the addition of a more precise analog-to-digital converter, the development of new software programs, and the construction of an electronic interface for the various components.

PUBLICATION

Zeisse, C.R., and Fisher, H.D., "The Measurement of Optical Transfer Function in Imaging Devices that Sample a Scene" (to be published)

ZR011.02
(NELC Z195)

Contact:
C. E. Holland, Jr., or C. R. Zeisse
NELC Codes 4300 and 2600
(714) 225-6860 or 225-6591

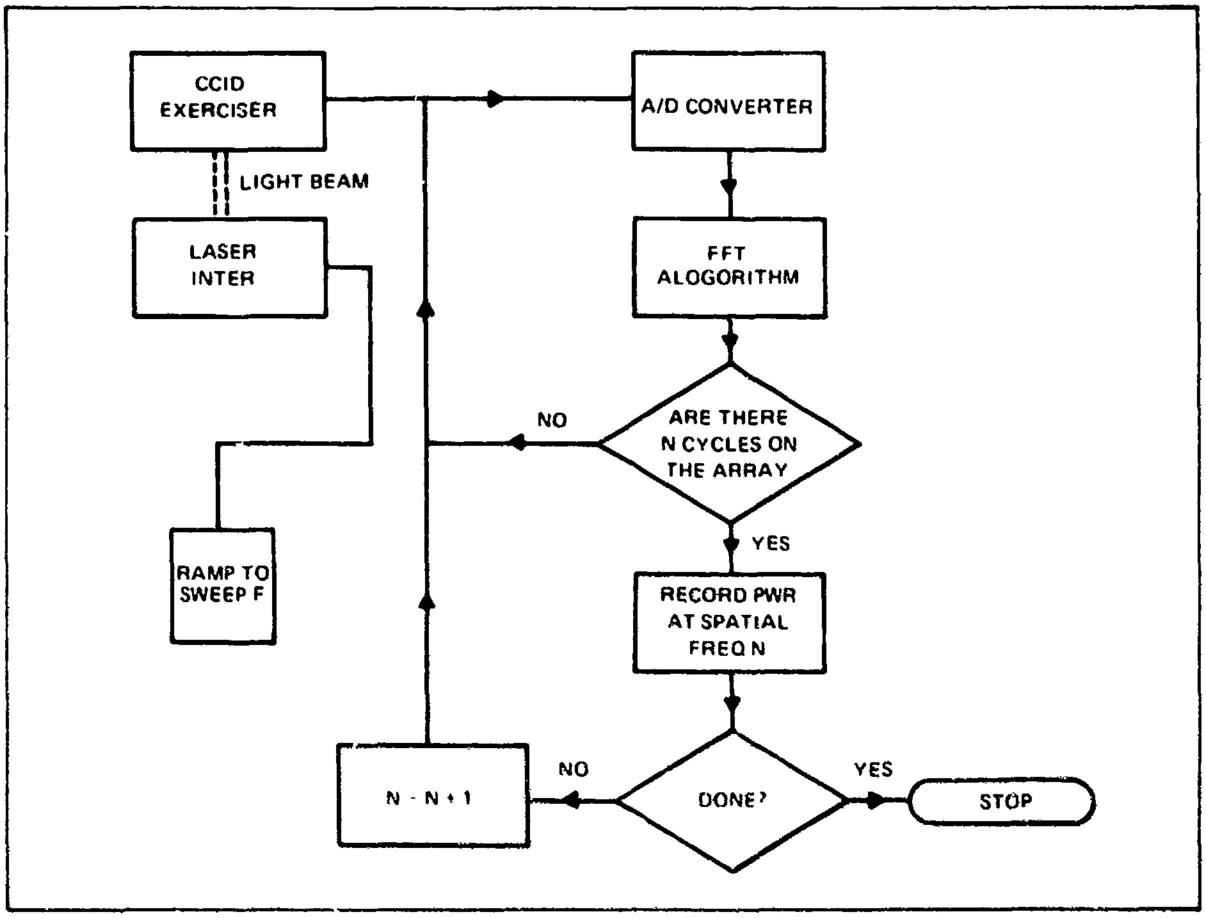


Figure 1. Signal measuring system. The interferometer irradiates the CCID. The output of the CCID is fed into an A/D converter, and a fast Fourier transform is performed on the series of samples, each sample originating from a single photosensitive element. As the spatial frequency is slowly swept, a computer algorithm is used to sense when there is exactly an integral number of cycles from one end of the CCID array to the other. When the condition is satisfied, the value of the transform is recorded.

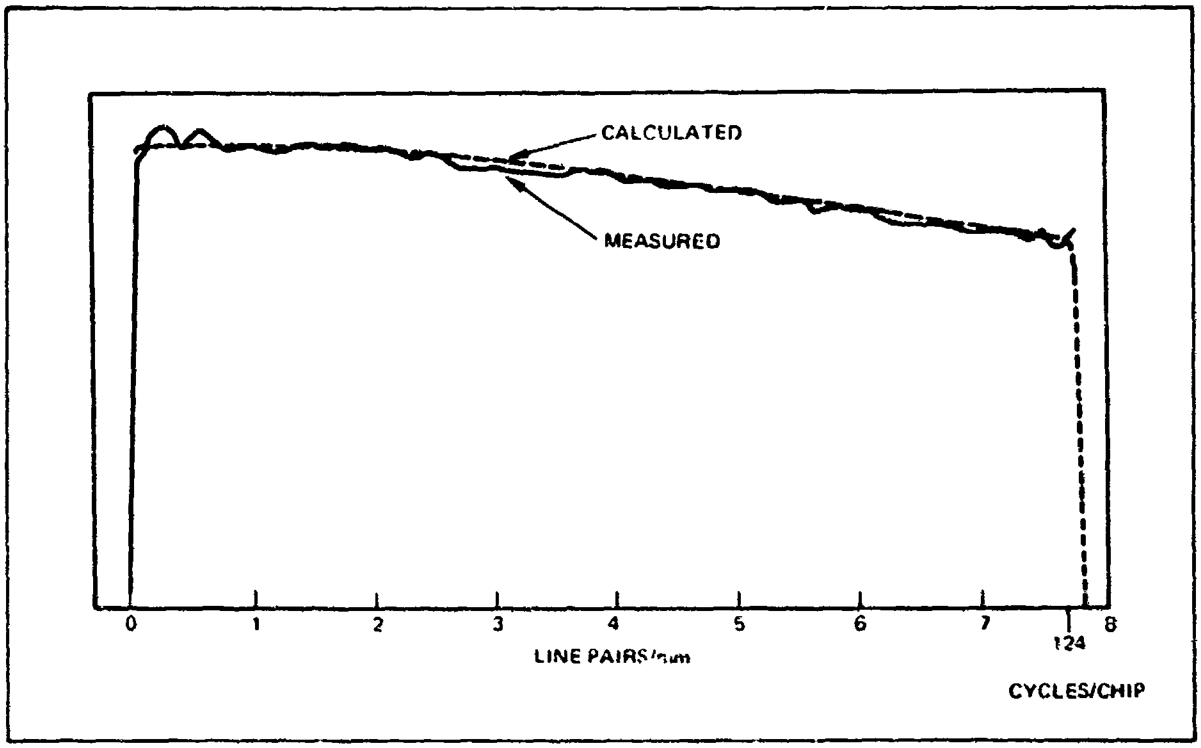


Figure 2. Calculated vs measured frequency response of a 500X1 linear CCID array. The calculated frequency response takes transfer efficiency and the shape of the photosensitive area into account.

Low-Light-Level TV IR Cathode

C. R. Zeisse

This program attempted to produce a photocathode with a long-wavelength threshold in excess of 1.1 μm via a new material (GaSb, a III-V semiconductor with a bandgap of 0.69 eV, or 1.8 μm) and a new technique (photosensitive field emission). The external electric field is produced by forming the semiconductor material into a tiny conical tip by means of an etching process.

The electrochemical etching technique for producing single tips from bulk bars of GaSb was greatly improved in FY74. The few usable tips previously obtained had to be selected from a large number of samples most of which were far too blunt for the production of the fields of 10^7 V/cm needed in field emission. Now suitable tips are produced about 50% of the time. Tip radii are in the vicinity of 1 μm, and the tip geometry is conical with full cone angles of 10° to 20°.

The flange used for measurements under ultrahigh vacuum was also improved. A tip can be heated to 500°C in this flange for surface cleaning and then cooled quickly and held at temperatures as low as 90K while the field emission current is measured. At 3×10^{-9} torr, currents as small as 10^{-11} ampere can be sensed at 5 kV.

Voluminous data have been taken with this flange over many decades of current under various conditions of cleanness and temperature. The data are typical of field emission from a metal. In many semiconductors, there is a deviation from this behavior throughout a certain voltage range. The deviation is sought in GaSb, because it is the region in which the field emission current is most sensitive to IR radiation, but it has not been seen.

Furthermore, the data display a lack of repeatability. In the 90K data there is a factor-of-20 variation in the current at any fixed voltage from one day to the next. It is common to observe a current jump by a factor of 10 at a fixed voltage. The source of the instability is unknown.

The major conclusion of this 2-year program is that the technology surrounding GaSb must be extensively developed before a good IR photocathode can be produced. A "good" photocathode would be uniform in response across its entire active area. Also, it would have very low "dark" current – would respond very little, that is, upon withdrawal of the IR radiation.

If the photocathode is made by etching an array of field emission tips in GaSb, (1) each of the tips must have an identical shape to within much better than 1%, and (2) the environment of the cathode will have to be closely controlled to prevent contamination of the cathode surface. The control of tip geometry will require the development of GaSb etching technology from its present rather primitive state to something resembling the present state of silicon etching technology. The control of cathode environment, however, seems to require ultrahigh vacuum, which is incompatible with practical tube technology.

ZR021.03
(NELC Z175)

Contact:
C.R. Zeisse
NELC Code 2600
(714) 225-6591

Solvated Electron/Solid System

S. J. Szpak

The broad objective of this investigation was to survey the practical aspects of solid-liquid junctions as they may apply to modern electronics. In particular, the survey was limited to the solvated electron/silicon system. This system was selected for one of its physical properties – the transition from metallic to nonmetallic conductivity displayed by the liquid phase.

When an alkali metal, such as lithium, sodium, or potassium, is dissolved in liquid ammonia, solvated electrons are created. If a semiconductor such as silicon is brought in contact with a solution containing solvated electrons and an electric field is applied, transfer of electrons from liquid to semiconductor or from semiconductor to solution must take place. Since no other reaction is likely to occur, this charge transfer may provide useful information concerning the interfacial region and allow us to follow the changes as the concentration of electrons in solution is increased; that is, until metal-like behavior is attained. It is felt that this approach may be of practical interest in solving problems associated with metal-semiconductor junctions – for example, determining the nature of the metal-semiconductor contact.

The study of the transfer of charge between certain liquids and semiconductors may increase our understanding of the interface region and ultimately reveal the nature of the metal-semiconductor contact. A method was developed in the course of this investigation for protecting cleaned silicon from recontamination on its way to the plating solution.

A limited number of experiments were carried out. In particular, the potential current relation associated with the interfacial charge transfer was determined and compared with results obtained when platinum metal was substituted for the semiconductor. The current potential plots for the n-type silicon were similar to those recorded for platinum. The curves for p-type were considerably different – they were displaced in cathodic direction. The behavior of p-type silicon is puzzling. More work is required in order to arrive at a satisfactory explanation.

In the course of this investigation, a novel method for the preparation of metal (nickel)-silicon junctions was developed. The silicon is cleaned in boiling KOH to remove oxide. It is transferred so quickly from the cleaning solution to the plating solution that its surface is protected from contamination all the way by a film of hot KOH. The KOH not only protects the silicon from recontamination, but continues to remove residual oxide until the silicon is safely in the plating solution.

The electroless nickel deposited onto both n- and p-type silicon (R = 1-5 ohms cm) yielded linear current potential plots over a considerable range of applied voltages.

ZR022.06
(NELC Z101)

Contact:
S.J. Szpak
NELC Code 2600
(714) 225-6591

Solid-State Mass Memory

INTRODUCTION

J. J. Symanski

The modern solid-state computer at the heart of almost every Navy system operates virtually instantaneously. The internal activity of a computer is measured in millionths of a second. But when data are needed from a large external storage device, "instantaneous" performance is no longer possible at the current level of technology. The accessing of mass memories -- drums and discs -- is currently an electro*mechanical* function, and it consumes significant amounts of time.

A purely electronic mass memory offering access to blocks of data at a hundred times the speed of drums and discs would be of enormous interest to the Navy for application in surveillance, communication, electronic warfare, and other systems in which time is critical. Preliminary work has been accomplished on several likely techniques. This program has investigated the use of charge coupled device (CCD) and magnetic bubble domain (MBD). While both techniques show promise, further development is needed before they can be utilized in demanding military applications.

Three articles on this subject follow.

Solid-State Mass Memory:

Solid-State Mass Memory — History

J. J. Symanski

Three years of investigation are described. Predicted characteristics of a CCD memory include a great reduction in access time from the access time required by the drum memory used with a standard Navy computer.

Memory has been a very important factor in computer systems from the beginning. It will continue to be and will probably become more important. The full spectrum of technologies in use and in various stages of development was studied in FY72. In FY73, effort was concentrated on the charge coupled device (CCD). Some basic system concepts were developed and test equipment was designed.

In FY74, several tasks were completed. Test hardware was put into operation which interfaced CCDs with a standard Navy computer. This was done for two reasons: first, to gain experience in utilizing CCDs in a system environment, second, to have the power of a computer to analyze the operation of the CCD.

Some prototype CCDs were obtained from a vendor. The major problem with them was sensitivity to supply voltages and temperature; that is, errorless operation could be achieved only over relatively narrow ranges of these parameters. The architecture of the chip is good, but more development is needed to make the device easier to apply in large systems.

Another facet of the work under this task was to determine how a CCD-type memory would fit into systems using standard Navy computers. The characteristics of the Navy computers were analyzed and recommendations made on implementing solid-state mass memory. The characteristics of the drum memory used with a standard Navy computer in the Message Processing and Distribution System (MPDS) were compared to the predicted characteristics of a CCD memory. It was shown that access time could be decreased by a factor of at least 100.

Concepts for the future development of CCDs and memory systems were also studied. The trends in electronic system design and the problems associated with design, fabrication, and maintenance were considered. Preferred approaches were developed which, if followed, could result in highly effective mass memory components for the Navy.

PUBLICATION

Symanski, J. J., Lagnado, I., and Keefer, R.L., "Charge Coupled Devices (CCDs) in Navy Memory Applications," NELC TR (in preparation)

ZR021.03
(NELC Z196)

Contact:
J. J. Symanski
NELC Code 3200
(714) 225-6515

Solid-State Mass Memory:

Bubble/CCD Tradeoff

H. H. Wieder

The magnetic bubble domain (MBD) is a competitor to the charge coupled device (CCD) for the mass memory function. The main advantage of the MBD is that it is nonvolatile. Some disadvantages are a somewhat slower data rate and a relatively unknown materials technology.

An assessment was made of past and current efforts to apply the kinematics of magnetic "bubbles," present in certain crystalline and amorphous ferromagnetic and ferrimagnetic materials, to the storing of binary-coded data. The most successful results obtained to date have been with rotating field-access modules, driven at rates between 0.1 and 1 MHz, using 20-k bit chips made of epitaxially grown rare earth ferromagnetic garnet layers overcoated with permalloy drive circuits, and including bubble generators and annihilators. These chips are organized in major-minor loop shift registers in block-addressed random-access configuration.

Magnetic bubble domain shift registers are slower than CCDs, but they have advantages which qualify them for consideration for certain fast-access and asynchronous buffer memories.

Although the bit rate capability of magnetic bubble domain shift registers is at least one order of magnitude slower than that of charge coupled devices, the inherent nonvolatility of stored information, their 100% transfer efficiency, and their immunity to moderate doses of high-energy radiation qualify them for consideration for a variety of fast-access and asynchronous buffer memories.

Continuous monitoring of the MBD technology is essential to allow evaluation of any new developments which might render the MBD more useful to the Navy.

PUBLICATION

Wieder, H. H., and Tomlinson, J. L., "Magnetic Bubble Domain Computer Memory Components," NELC TN 2598, 29 January 1974

ZR021.03
(NELC Z196)

Contact:
J. J. Symanski or H. H. Wieder
NELC Codes 3200 and 2600
(714) 225-6515 or 225-6591

Solid-State Mass Memory:

Novel CCD Structures

I. Lagnado

An effort carried out in FY74 has established the technological base to assess the application of charge coupled devices (CCDs) to low cost serial memory stores and to design, fabricate, and evaluate particular structures optimized and made consistent with memory system requirements

The possible usefulness and applicability of CCDs to sequential memory stores were assessed. The preliminary conclusion, based on the consideration of both economic and technical feasibility, is that CCDs narrow the gap between low cost, large capacity magnetic discs and drums and expensive, small, high performance semiconductor RAMs.

The economic aspect of the study dealt with yield cost projections based on the assumptions that accepted equations are used to calculate yields, 3 inch wafers are processed, and manufacturing costs alone are considered

To illustrate this part of the study, three different chips are considered a 32 , a 50 , and a 100 kbit charge coupled memory device The cost decrease from year to year is based on the systematic and progressive reduction in defects generated by the manufacturing process or initially present in the substrate material 25 and 40 per year decreases in defects were considered Table 1 (40%) shows "Production Cost Bit" figures as the manufacturer's cost, exclusive of temperature and high frequency tests The customer cost, affected by product specifications, may be an order of magnitude higher Since the manufacturing costs discussed here are component costs, the system cost is obtained, by a rule of thumb, to account for all peripheral overhead, such as power supplies, circuit boards, and cooling To this end, a multiplication factor between 3 and 5 is usually applied to the device price per bit.

Chip A (32 kbit)					
Year	EDS Yield %	Net Die Wafer	Die Cost*	Production Cost** $	Production Cost Bit ¢
1975	4 13	46 7	1 61	4 6	0 0177
1976	58 8	66 5	1 13	4 13	0 0159
1977	73 4	83	0 9	3 9	0.015
1978	83 8	94	0 79	3 79	0 0145
1979	91 5	103 5	0 725	3 725	0 0143
Chip B (50 kbit)					
Year	EDS Yield %	Net Die Wafer	Die Cost	Production Cost $	Production Cost Bit ¢
1975	18	22	3 16	6 16	0.0123
1976	46 6	36 6	1 91	4 91	0 0099
1977	64	50 3	1 39	4 39	0 0088
1978	77	60 9	1 15	6 15	0 0083
1979	88	69 2	1 01	4 01	0 008
Chip C (100 kbit)					
Year	EDS Yield %	Net Die Wafer	Die Cost	Production Cost $	Production Cost Bit ¢
1975	17 7	10 2	7 35	10 35	0 01
1976	35 4	20 4	3 68	6 68	0 007
1977	54 5	31 5	2 36	5 36	0 005
1978	70 7	40 9	1 83	4 83	0 0048
1979	84 1	48 5	1 54	4 54	0 0045

* @ $75/wafer

** Assuming packaging cost at $3 die (before final test)

TABLE 1 (40% PER YEAR DECREASE IN NUMBER OF DEFECTS D)

Analytical and experimental investigations show the CCD to be an economically and technically feasible means for narrowing the gap between low-cost, large-capacity magnetic discs and drums and expensive, small, high-performance semiconductor random-access memories. Buried-channel is recommended over surface-channel structure for Navy systems use since it provides a mean time between errors in excess of 10^{29} hours.

The cost per bit for chip C is seen to be about 0.005¢ by 1979. Applying first a conservative factor of 10 to account for dynamic testing and to insure temperature performance (military specifications) and then another multiplication factor of 5 to obtain the overall system cost, it is found that the single-bit cost rises to 0.25¢. A 20-megabit memory store using charge coupled devices would then be priced at 2×10^7 bits $\times$ 25×10^{-4} \$/bit = \$50 000.

The technical feasibility for a memory store based on charge coupled device modules is deduced from the technology parameters. Advances in technology, such as the use of an electron projection system for masking and alignment, enable a drastic reduction in bit size and a consequent increase in bit packing density. However, the resulting decrease in charge capacity carries the risk of an unacceptable bit error rate - in particular for surface-channel technology. On the other hand, the use of deep buried-channel structure (the peristaltic approach) allows higher clocking rates – up to 150 MHz – thus reducing the access time. The peristaltic structure is seen as the vehicle allowing the CCDs to compete with faster semiconductor devices for cache or buffer applications.

The viability of a new technology depends on its acceptability and marketability to system applications. Due to the inherent operational principles of CCDs, there exists a probability of error when reading out binary signals at the output of the device. The bit error rate in memory systems was thus addressed in order to adjust the technology parameters at the chip level to be consistent with system requirements. The study shows that within the temperature range -55 °C to +75 °C, for large memory stores of the order of 10^8 bits, the surface-channel configuration satisfies the requirements for a mean time between errors (MTBE) of $5 \cdot 10^5$ seconds (about a week) if the bit size is close to 400 μm^2, which allows the packaging of 32 000 bits into a memory chip 200 to 250 mils on a side. Higher densities may not be possible, since the minimum bit area is determined as a function of (1) semiconductor processing variables such as surface-state density N_{ss} which must be controlled at a level of about 10^9 states/cm^2 · eV, (2) recirculating clock frequency, (3) size or number of carriers N(0) representing a binary zero, and (4) ratio of N(1)/N(0), to be kept around 5. These constraints may be too severe to be satisfied simultaneously and reproducibly. To alleviate the problem, the buried-channel structure provides an optimum solution; furthermore, the latter affords a substantially higher bit density/unit area. For a 100-kbit buried channel chip, the mean time between errors (MTBE) within the operating temperature range of -55 °C to +75 °C is in excess of 10^{29} hours.

The experimental portion of the program established the technological base here for CCD design and application of digital systems. Consistent with block-oriented, random-access memory, a novel configuration based on a major/minor loop concept was designed, fabricated, and tested at NELC. A photomicrograph is shown in figure 1. Preliminary results have determined a charge transfer efficiency of 0.999 up to 1 MHz for this technology. Data were circulated around the loop four to five times with no catastrophic signal degradation, for an excess of 600 bits or 1800 transfers. The equivalent time delay for this number of transfers at 100 kHz is 18 msec. This performance strongly indicates potential application in sonar or IFF systems.

Well conceived experiments should be planned to verify the bit-error rate obtained from the analytical study. By use of the above CCD and closed-loop structure, a specific bit pattern produced by computer would be entered into the device, circulated, detected, generated, reentered, and compared to the original train of pulses by the same computer. Facilities are available at NELC for implementing this experiment.

ZR021.03
(NELC Z196)

Contact:
I. Lagnado
NELC Code 4800
(714) 225-6877

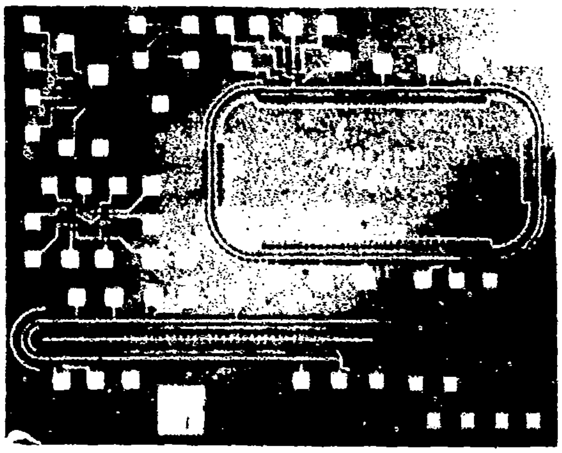
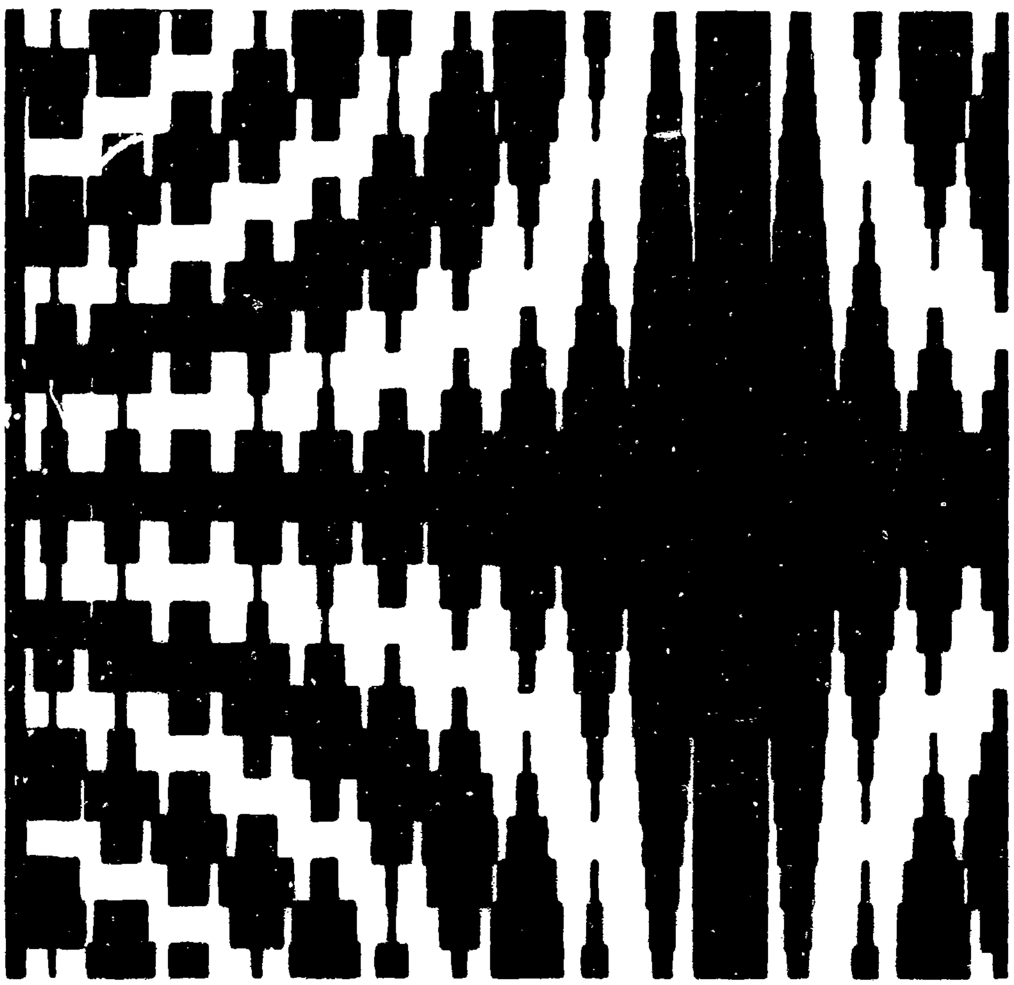


Figure 1. Closed-loop, n-channel, metal-gate, three-phase, 152-bit CCD.

Signal and Information Processing



Signal Processing Imager Using Charge Coupled Devices

I. Lagnado

The device described here uses charge transfer techniques to facilitate hardware implementation of two-dimensional filtering by accomplishing signal measurement and signal processing in a single device.

In the current effort, the application of charge coupled devices (CCDs) to the processing of optical images is studied. Of particular interest are the areas of optical correlation and image transformation. Cross correlation uses spatially uniform, time-varying illumination. Transform image encoding uses spatially varying illumination which is constant during the processing interval. However, present technological constraints and or stringent performance requirements severely limit the capabilities of processors mechanized by known techniques or old concepts. For instance, the "transpose" memory needed in the implementation of an image transform is beyond the state of the art. Similarly, the general applicability of an optical correlator to different signal processing functions is unnecessarily restricted by the required interchangeability of different optical masks.

To eliminate present system constraints, it was proposed that existing charge coupled linear arrays be modified to permit independent control of the charge transfer gate. In a cooperative project, workers from the Naval Undersea Center and NELC carried out the mathematical formulation and verification of this concept and its practical implementation into a new device which combines the functions of signal processor and image sensor in a single photosensitive silicon charge coupled device. Such a device was designed and, after commercial fabrication, evaluated here. A schematic of it is shown in figure 1.

It was demonstrated experimentally that the principle of simultaneously measuring an optically incident signal and performing a linear mathematical transformation upon it is feasible. The experimental verification of the new concept is presented in the form of a convolution/correlation function as measured at the output of the device. The output is seen as the algebraic sum of terms which account for all past excitations – each term being the product of the sensing element signal with a parameter set by the digital timing sequence applied to the transfer gate.

The performance of the device is shown in the series of oscillographs of figures 2 and 3, which clarify its operational principles and demonstrate the accuracy of the mathematical analysis (ref. 1-3). The triangular waveforms are the expected output shape when all charges are transferred to the right or to the left and the light source (a light-emitting diode) is switched off after 256 transfers. Figure 2 illustrates the case in which the last potential well is filled to saturation. The triangle apex corresponds to a full CCD bucket, or $5 \cdot 10^5$ electrons. Figure 3 illustrates the case of a maximum charge of 5000 electrons after 256 summation transfers. The contribution for each CCD well (or photosensing element) is about 20 electrons. The device sensitivity is, however, limited by the dark current level and its uniformity.

Figures 2 and 3 demonstrate the capability of a dynamic range of at least 100:1. Dark current and noise levels are the fundamental constraints. A frequency range of about 100:1 is also achieved. A final criterion to be satisfied is the ability to modulate both transfer gates, employ a double sample-and-hold circuit to separate the outputs from both CCD shift registers, and perform the summation to achieve the convolution/correlation function. This is shown in figure 4.

The practical uses of this device are numerous. The principal ones are (1) as an image transform – in bandwidth reduction, noise protection, differential motion measurement, and pattern recognition; and (2) as an optical correlator – in spectrum analysis, matched filtering communication detection, and 2-D Fourier transforms.

During FY75 it is planned to investigate practical solutions for the implementation of complex arithmetic needed for elaborate computations, such as in the discrete Fourier transform with Fast Fourier Transform (FFT) or chirp-z transform (CZT) algorithms.

REFERENCES

1 Lagnado, I., NELC, and Whitehouse, H.J., NUC, "Concept of a Signal Processing Imager Using CCD," 1973 CCD Applications, NELC, 18-20 September 1973, *proceedings*

2 Lagnado, I., NELC, and Whitehouse, H.J., NUC, "Signal Processor Image Sensor Using CCDs," to to be presented to the 1974 CCD Application of Technology Conference, Edinburgh, Scotland, 25-27 September 1974.

3 Bond, J.W., "Structural Organization for Real and Complex Convolution by Imaging CCD," Naval Undersea Center TN 1306, 1974

ZR021.03
(NELC Z194)

Contact:
I. Lagnado
NELC Code 4800
(714) 225-6877

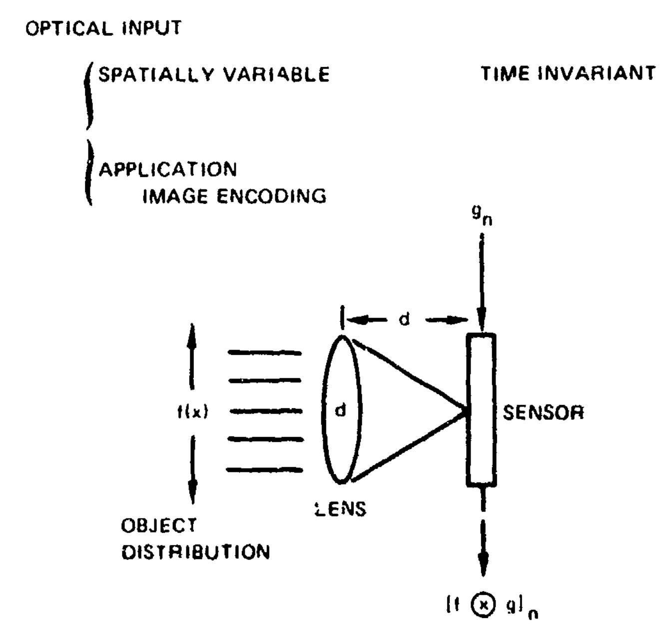


Figure 1. Configuration for an image encoder.

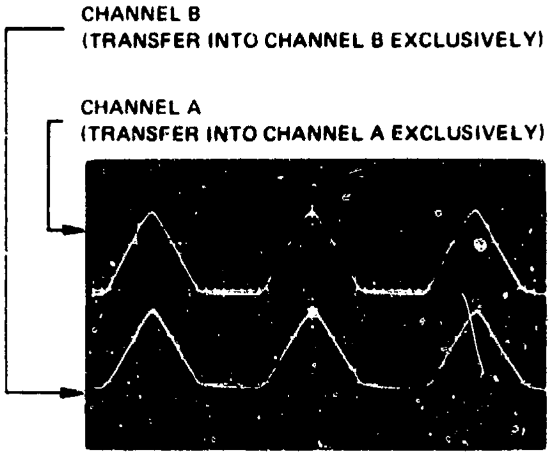


Figure 2. *Operation of the device when saturated. 2V/vertical division, 1 msec/horizontal division.*

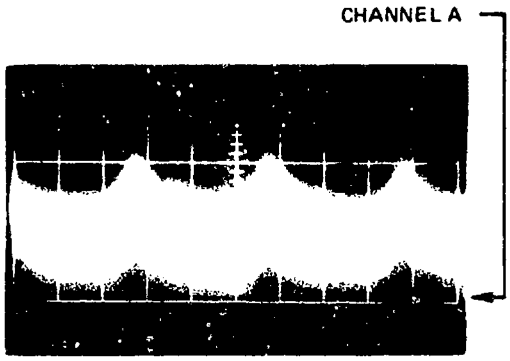


Figure 3. *Signal level 100 times smaller than that shown on figure 2. 0.05 V/vertical division, 1 msec/horizontal division.*

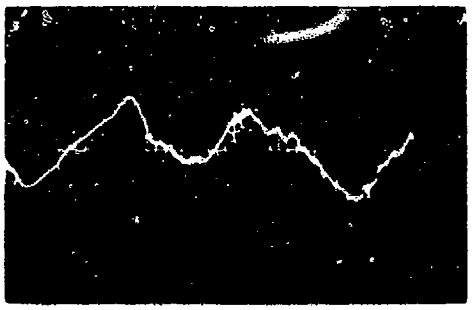


Figure 4. *Experimental evidence of convolution/correlation obtained when digital patterns 1101 and 0010 are applied to channels A and B, respectively. f = 1.2 MHz.*

Small Ship Command Control System [SSCCS]

D. G. Mudd

Smaller Navy vessels need command control just as larger ones do, but existing systems are obviously unsuitable. The "distributed processor" concept would supply a cost-effective system tailored to the needs of each small ship class by employing standard general-purpose microprocessors, special-purpose hardware as needed, and flexible data busing. Analysis has validated the concept.

The Small Ship Command Control System (SSCCS) was initiated in 1972 as an exploratory development effort aimed at providing an integrated command control system for the growing fleet of smaller Navy ships including, for example, hydrofoils, patrol frigates, surface effect ships, and destroyer escorts. These ships will require significantly different command control capabilities, and SSCCS has been planned as a generic system development capable of configuration to meet each ship's requirements as they become defined. Presently, the high cost of existing command control hardware and software severely limits the number of ships with effective command control systems.

The primary objective of SSCCS is the utilization of advanced technology to define low-cost alternatives to present shipboard command control systems. The development of a distributed processor for SSCCS was identified as such an alternative with high potential payoff both in the hardware and software development and acquisition cycles.

In order to develop this concept and prove its feasibility, a set of detailed processing requirements was defined, based upon existing and projected command control systems for small ships. This definition included a description of the required processing functions, such as navigation, tracking, and data links, in addition to the computer storage, speed, and interface requirements for each function. A distributed processing architecture, meeting the established processing requirements, was then described at a functional level. The basic design utilized low-cost microprocessors, each dedicated to a unique function, as the basic processing elements. Communication between these elements, a stringent requirement for real-time command control systems, is achieved by means of an asynchronous data bus operating at a maximum rate of 1 million data bits per second. The bus design includes features to reduce the complexity of the system software, particularly in the executive software area, in an effort to transform a network of low-cost, moderate-capability microprocessors into a modular and expandable equivalent of a powerful single computer. Analysis and simulation of this architecture have proved that the basic distributed processing concept will meet the projected requirements and is an effective method of applying low-cost microprocessors to the command control problem.

The development of hardware to demonstrate the distributed processing concept, and allow further evaluation of it, was also initiated in FY74. In particular, bus hardware circuitry has been designed, and commercially available processors have been procured for configuration into a four-processor baseline system. In addition to allowing technical evaluation of the architecture, the hardware will be interfaced to Naval Tactical Data System display equipment and selected display and tracking functions will be implemented in order to demonstrate the concept in a command control environment.

Related tasks which were impacted by this project during FY74 included the definition of processing requirements and the recommendation of a currently available military processor for the combat direction systems in destroyer escorts, guided missile destroyer escorts, and guided missile destroyers. Much of the data to support core sizing and timing estimates for the AN/UYK-20 computer were extracted from data derived in SSCCS.

PUBLICATIONS

Pasahow, E. J., "Small Ship Command Control System–System Description," NELC TD 318, June 1974

Pasahow, E. J., "Alternative Microprocessor Configuration Study," NELC TN 2711, 12 June 1974

Pasahow, E. J., "A Simulation of the Small Ship Command Control System," NELC TN 2725, 27 June 1974

Bayless, T. H., "A Distributed Processing Concept for Small Ship Command Control–Expected Payoffs and Risks," NELC TN (to be published)

ZF61.212
(NELC Z270)

Contact:
D. G. Mudd
NELC Code 3300
(714) 225-6258

Voice and Image Data Companding

INTRODUCTION

D. O. Christy

The following three articles deal with the development of a phonemic vocoder for the transmission of voice by existing Navy assets with high fidelity and intelligibility; with the compression of images via transform encoding techniques prior to digital transmission; and with the design of data compression hardware incorporating the Schalkwijk algorithm.

Apparently unrelated, voice processing and image processing are based on common mathematical techniques. Furthermore, equipment developed for image processing may be applied to voice processing, and certain voice processing techniques—such as linear prediction coding—can be applied to the transmission of certain types of images. Indeed, the data compression techniques reported may be applied to any digital communication channel that contains redundant information.

Voice and Image Data Companding:

Phonemic Vocoder

D. O. Christy

BACKGROUND

Implementation of a phonemic vocoder requires the application of three technologies: present-day vocoder architecture, speech understanding systems technology, and phonology and acoustics. This development effort was directed at:

- Collecting and evaluating data on speech and electronic techniques for extracting useful speech information.
- Developing software and hardware tools for extracting information from speech.
- Testing the tools acquired.
- Evaluating vocoder concepts and measuring their effectiveness.
- Implementing and evaluating the most promising vocoder concepts.
- Exploring and solving high-risk critical processes or techniques.
- Designing and implementing a phonemic vocoder.

ACCOMPLISHMENTS

An entire family of programs for emulating a phonemic vocoder on the IBM 360 computer was developed, debugged, and evaluated. Included were a linear prediction coding (LPC) analyzer whose outputs were processed by an area function extractor; cluster analysis and classification programs; instantaneous period determination and tracking programs for processing of instantaneous period output data to complement the data from the area function extractor; and a hidden Markov segmenter which utilized data from the classifier.

Four different pitch extraction methods were software implemented and evaluated, of which the first utilized J. Markall's concepts, the second was developed from N. Miller's concept, the third used pitch projection for determining pitch, and the fourth utilized various speech signals with appropriate weights for pitch determination. A pitch movement analyzer program monitored the pitch, pitch change, and pitch acceleration with respect to speech synthesis. A phonemic driver program which generated area functions from the tokens of speech was designed and implemented. Also implemented were a program which formed an acceleration profile and generated frame-by frame area functions from which the LPC Parcor parameters were evaluated, and an LPC synthesizer with pitch data programs for generating digital output.

To support development of the phonemic vocoder, the following programs were developed or acquired and evaluated: a pole extraction and selection algorithm, Atal's LPC, and a Normix cluster analysis program. An improved labeling system and improved software for the VIP 100 were implemented. Various studies of speech samples were conducted by use of the cluster analysis program, either on all the speech or on the voice segments of speech only. Various tradeoffs were performed via cluster analysis and classification techniques evaluating the applicability to the phonemic vocoder of LPC parameters, area function parameters, area function ratio parameters, instantaneous frequency, and instantaneous frequency tracking. A phonemic transcription of a segment of speech was made for relating the classification processes. Fricatives and voiced fricatives were studied, as were phonemic environments, to determine the requirement for transition probabilities and pitch contour.

This project is devoted to the design and implementation of a device for the extracting from human speech of useful information and the coding of it for transmission by digital techniques. Voice encoders and decoders already exist, but current Navy transmitting assets cannot meet their data rate requirements. The problem is therefore to reduce the number of bits required for the transmission of voice at high levels of fidelity and intelligibility.

To aid in the development of speech data acquisition and analysis, D/A and A/D conversion of speech, a quiet room, audio mixers, audio jack panels, audio tape unit, and interfaces with the VIP 100 discrete word recognition system and the VOTRAX synthesizer were implemented. A general interface between the audio equipment and a disc drive and processor was designed and implemented. This interface consists of a low-level microphone preamplifier, AGC

circuits, preemphasis circuits, D/A and A/D converters, variable sampling rate control, and filter interface. It also includes a cache memory, cache memory control, disc interface, and interface with the processor. Software for the processor was designed and implemented to exercise the cache memory and to exercise and test the disc. A disc handler was also designed and implemented. In direct support of the brassboard phonemic vocoder development, a log counter, an instantaneous period log compressor, and an automatic wiretab program were constructed. The implementation of LPC by analog hardware was studied. A high-level block-component design and a gross mechanical design of a phonemic vocoder brassboard model were prepared.

Implementation of a phonemic vocoder is of extreme importance to the Navy. The problem consists of reducing the number of bits needed for the transmission of voice with high fidelity and intelligibility by presently available Navy assets, which are incompatible with the high data rates of present-day vocoders.

PUBLICATIONS

Wilts, J. R., "Computer Programs for the Phonemic Vocoder," NELC TN (in preparation)

Edmondson, G. D., "A Time-Domain Waveform Display/Analyzer for Speech Research," Naval Postgraduate School, Monterey, California, June 1974 (master's thesis)

Christy, D. O., "A Phonemic Vocoder Design," NELC TN (in preparation)

Christy, D. O., "Technical Trade-offs in a Phonemic Vocoder Design," NELC TN (in preparation)

ZF61.212
(NELC Z268)

Contact:
D. O. Christy
NELC Code 3200
(714) 225-6515

Voice and Image Data Companding:

Transform Source Encoding

D. C. McCall

During the first part of FY74 software was written to interface the output of the digital frame capture unit (DFCU) with computer programs which simulate a digital image transmission system. The DFCU was acquired during FY73 and provided the capability to do in-house digital image processing. The equipment is designed to accept TV images, convert them to digital format, and store them for subsequent transfer to digital tape. The DFCU also accepts data from a digital tape for video display. With this capability we were able to emulate a digital image transmission system with computer programs and illustrate the effects of three-to-one and six-to-one compression of a digitized image via transform encoding techniques.

The emulated image transmission system is shown in figure 1. The role of the image reader is played by the DFCU, which produces digitized images on IBM-compatible magnetic tape. The tape is used as input to the computer program which emulates the block organization, transform source encoder, channel, and decoder. The processed image is written onto magnetic tape for display on the DFCU. As indicated in the block diagram, a coded version of a linear transformation of the image is transmitted rather than the image itself. The motivation for using this technique is that coding the spectral components of pictorial sources provides higher coding efficiency, computational simplicity, increased noise immunity, and exact control on the compression ratio.

The Walsh transform, an expansion in terms of rectangular waveforms, and the slant transform, an expansion by sawtooth waveforms, were evaluated in the encoding scheme with respect to preservation of fidelity for the same compression ratio, cost of implementation, and speed of operation. Walsh functions are binary, and the discrete Walsh transform of a data vector requires only additions and subtractions. The slant transform requires multiplications and a two-dimensional format for implementation, and the inverse transform differs from the forward transform. At a three-to-one compression ratio the transform used—Walsh or slant—causes no appreciable visual difference in images transmitted. Therefore, the Walsh transform was selected as the preferred transform.

During FY74 the image transmission system processed images at three-to-one, four-to-one, and six-to-one compression ratios. Images can be transmitted at a three-to-one compression ratio with no appreciable loss of fidelity. Noise was added to the encoded bits at the rate of one bit per 1000 on the average with little effect on the received image. At six to one, the block organization begins to show up, and the fine details become smoothed during the encoding.

Walsh and slant transform encoding techniques were compared. In performance they differed little, but the Walsh transform was favored on the basis of simplicity. It is binary, and the transformation of a data vector requires only additions and subtractions. The effects of compression of digitized images via these transforms were demonstrated. Three-to-one compression does not appreciably affect detail. Deterioration begins at six to one.

A design for implementing the discrete Walsh transform was worked out at the functional block diagram level. An initial hardware cost estimate for a breadboard model which would compute the 16-point discrete Walsh transform (six bits' resolution per point) is $2k. The estimate assumes the use of commercial components and operation at video rates. A 16-point input represents a block organization size of four by four. Although theoretically it is somewhat better to process larger blocks, the cost for working storage goes up exponentially with increase in block size.

PUBLICATIONS

McCall, D. C., "Data Compression Using Walsh Transform Source Encoding," *Naval Research Reviews*, XXVII, p49–56, May–June 1974

McCall, D. C., "3 to 1 Data Compression Via Walsh Transform," NELC TR 1903, 10 December 1973

Dillard, G. M., and McCall, D. C., "Discrete Transform Techniques Applied to Signal Processing," NELC TN 2698, 20 May 1974

ZF61.212
(NELC Z268)

Contact:
D. C. McCall
NELC Code 3300
(714) 225-7777

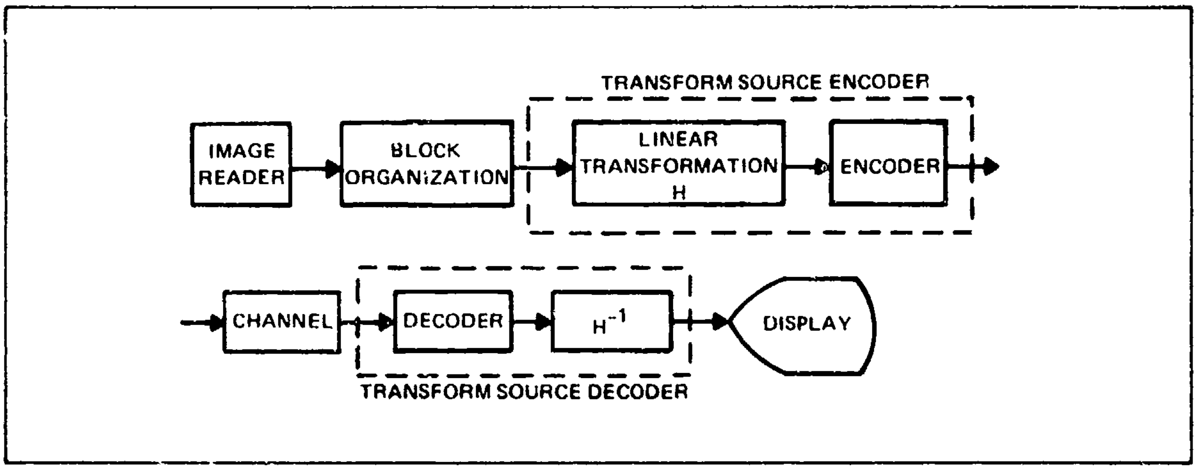


Figure 1. Emulated image transmission system.

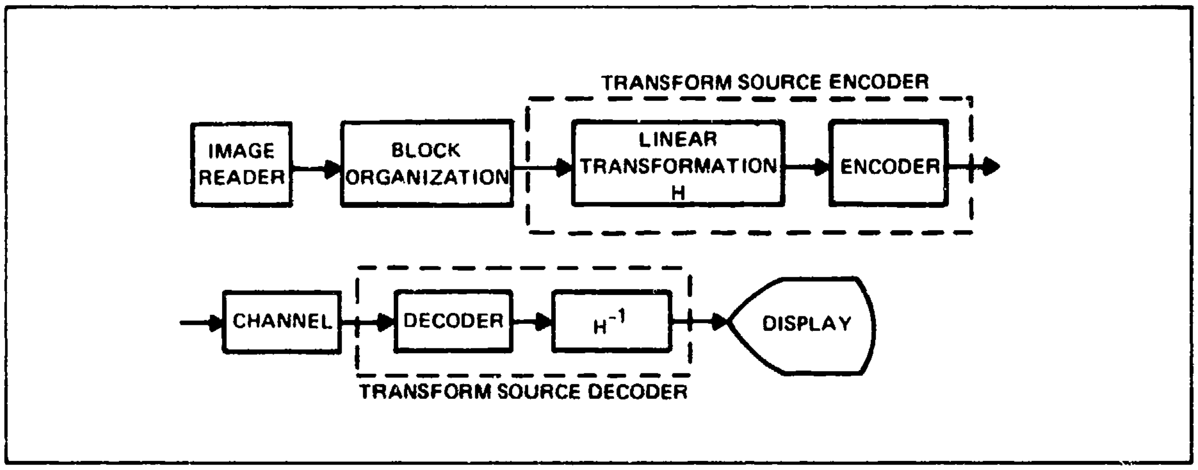


Figure 1. Emulated image transmission system.

Voice and Image Data Companding:

Schalkwijk Source Coding

J. C. Lawrence

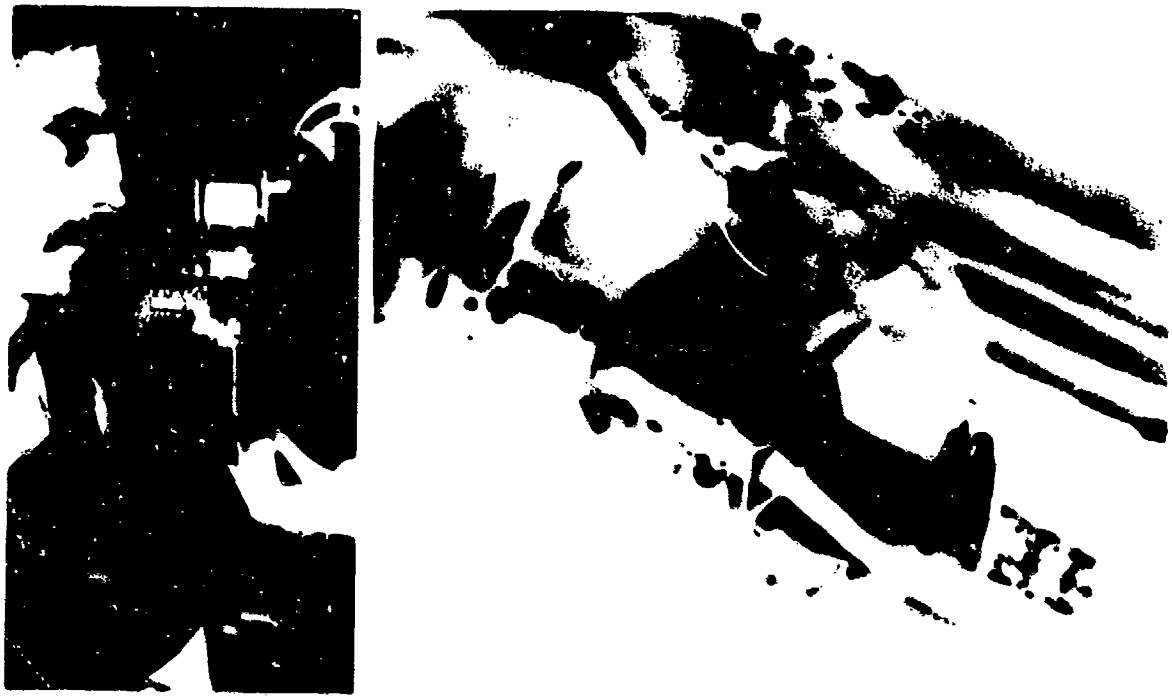
The computer algorithm developed in FY73 was used as a basis for redesigning the data compression hardware. During FY74 the hardware (encoder-decoder) was designed for testing on very-high-resolution pictorial data. Debugging of the encoder was completed and preliminary tests resulted in compression ratios on two different pictures of approximately three to one and four to one with no loss of information.

The data compression techniques are applicable to any digital communication channel that contains redundant information. For example, the TRI-TAC facsimile program has a need for data compression in the transfer of facsimile information. The hf link conveying facsimile data from weather centrals to ships could utilize data compression to reduce transmission time. Additionally, sufficient redundancy may occur in digital voice (vocoder) that the Schalkwijk algorithm could be advantageously employed.

ZF61.212
(NELC Z268)

Contact:
J. C. Lawrence
NELC Code 2400
(714) 225-6562

Electro-Optical Technology and Applications



Preceding page blank

Fiber Optics Tactical Data Link MTACCS [Marine Corps Tactical Command Control System]

J. J. Symanski and D. N. Williams

Reducing the weight of transportable systems by the substitution of fiber optics bundles for heavy coaxial cable is an attractive possibility. Marine Corps computer systems in particular suffer from the weight of MIL STD 90-pin-connector armored cabling. Under this task a fiber optics cable will be developed to connect two transportable huts containing the Marine Corps CP642B computer and the AN/TYA-20 data terminal, cabinets will be designed to hold the interface fiber optics circuitry (serial-to-parallel and parallel-to-serial conversion), and circuitry will be developed and cards fabricated for use in the cabinets. (Development of the converter circuitry itself was partially funded under another project.)

The original specification for the serial data rate was 20 MHz, or 50-ns pulses, in a specified pattern ranging from 10% to 70% duty cycle. The available light-emitting diodes could not be used at this rate. A design change reduced the serial rate to 5 MHz, which is adequate for the two equipments of interest.

When the fiber optics cable system is completely developed, it will demonstrate a significant weight and size savings over present Marine Corps wire cables. The most significant contributions of the fiber optics, however, may prove to be the immunity provided to electromagnetic interference and electromagnetic pulse, and the electrical isolation achieved from the transmit end to the receive end of the cable.

The Marine Corps has approved plans for a feasibility demonstration of the completed system and designated a facility as the test site. One interconnecting cable will be replaced with the fiber optics cable plus the needed interface circuitry. The results of tests over several months of operation will be evaluated to determine whether further development is warranted.

ZF61.212
(NELC Z271)

Contact:
J. D. Hollobaugh, J. J. Symanski, or D. N. Williams
NELC Codes 1700, 3200, and 2500
(714) 225-7533, 225-6515, or 225-7570

Narrowband Underwater Laser and Detector

INTRODUCTION

E. J. Schimitschek

Communication, detection, and ranging systems operating either between aircraft and submarines or submarines and submarines are of mounting interest within the Navy, and at least two systems are being actively pursued. High efficiency of the blue-green source and correspondingly narrow bandwidth of the detector are key factors. The interrelationship of peak power, pulse width, average power, maximum attainable depth or range, and signal-to-noise ratio is also important.

NELC has developed an analytical model which takes into account the attenuation and scattering of different types of ocean water and the scattering of the air-water interface. System analyses based on this work are performed for other proposed or conceivable systems to determine the performance which could be expected if the optimum source and detector combination were available for the application.

The study will be useful in (1) determining what kinds of systems are practical and (2) setting up requirements for sources and detectors for optimum system performance. The program, which is described in the following three articles, should have direct impact in the areas of short-range underwater detection and communication among ships, submarines, and aircraft.

Narrowband Underwater Laser and Detector:

Analytical Performance Study of Lasers in Underwater Systems

R. D. Anderson

Three applications of particular interest received study under this task. They are discussed below.

The first concept advanced for study was a strut-mounted underwater ranging and detection system for detection of submarines from hydrofoil patrol craft (PCH). It was recognized at the outset that severe engineering problems would be encountered in mounting equipment on the lifting structure of hydrofoil craft. The problems were not only structural but hydrodynamic in nature, representing compromises in vessel performance. Another area of uncertainty involved cavitation in the window area and the ability to maintain a clear optical aperture while underway. The basic requirement addressed was the more fundamental concern of range capability of such a system. Analysis shows that existing laser technology can provide a system which will detect submarines at slant ranges of about 490 feet in cold, open ocean water. ($\alpha = 0.1\ m^{-1}$). Dye laser developments could extend this capability only marginally, to approximately 550 feet. Since these ranges are comparable to the turn radius of the vehicle, such a system would fail to provide a tracking capability to a PCH for ASW operations.

The impact of several blue-green transmitters on different Navy underwater systems was compared. It was found that a dye laser would greatly improve performance of underwater surveillance and communication systems.

Second, performance of underwater imaging systems of the flood and dual-scan illumination types was evaluated for several illumination sources, including arc lamps, strobe lamps, incandescent lamps, and lasers. The comparison of system performance utilized a performance figure of merit based on the assumption that the vehicle was power-supply limited. Two types of ocean waters, coastal and deep ocean, were considered. In the evaluation, the dye laser appeared to outperform all other sources. This can be attributed to the unique wavelength tunability of the dye laser and its relatively high efficiency.

Third, analysis based on detection theory was used to define a figure of merit for optical transmitters used in underwater communication systems. The figure of merit, which is relatable to system available signal-to-noise ratio, is then applied to a number of candidate optical transmitter sources. The results of the analysis showed that the dye laser is the superior transmitter for both near-term and future applications.

ZR011.07
(NELC Z198)

Contact:
E. J. Schimitschek or R. D. Anderson
Code 2500
(714) 225 7975

Narrowband Underwater Laser and Detector:

Blue-Green Lasing Dye Studies and Excitation Source Development

E. J. Schimitschek, J. E. Celto, and J. A. Trias

The utility of blue-green lasers in underwater systems will be increased by (1) the synthesis of coumarin dyes showing exceptional stability under flash excitation, (2) an extended-life flashlamp for dye excitation, and (3) the enhancement of dye fluorescence via the use of mixtures of several dyes.

The blue-green dye laser is expected to have considerable impact on future Navy underwater communication and illumination systems. The following contributions to the technology may prove significant.

Under a joint effort with Naval Weapons Center, whose work was internally funded, about a dozen new coumarin dyes were synthesized and tested for laser performance and photochemical stability. Some show exceptional stability under flash excitation. From the pattern which is developing from comparisons of these related dyes, it is now possible to get leads for further synthesis work.

A linear xenon flashlamp test and evaluation program, started in in FY73 under another project, was continued and completed in FY74. Data were obtained on the optimum fill pressure and electrode geometry for long lamp life. Several processes, in particular cathode sputtering, limit lamp life. As one attack on the sputtering problem, work was started on an inductively coupled, electrodeless annular lamp for dye excitation. Initial tests indicate that this lamp can be operated efficiently if the circuit parameters are carefully adjusted. For this purpose a thorough computer analysis was performed on the tradeoffs between individual circuit elements.

For several Navy missions, efficient and tunable continuous-wave laser power in the blue-green is required. Present cw dye lasers are pumped with argon lasers, which are inherently inefficient. This problem might be eliminated if incoherently pumped dye lasers could be developed. For this purpose, threshold calculations were performed and dye fluorescence enhancement by using mixtures of several dyes was studied. Initial results are promising.

PUBLICATIONS

Schimitschek, E., Trias, J., Hammond, P., and Atkins, R., "Laser Performance of Fluorinated Coumarin Dyes," *Opt. Comm.* (accepted for publication)

Celto, J., Schimitschek, E., and Trias, J., "Voice Communication with a Flashlamp-Excited Blue-Green Laser," NELC TN 2672, 24 April 1974

ZR011.07
(NELC Z198)

Contact:
E. J. Schimitschek, J. E. Celto, or J. A. Trias
Code 2500
(714) 225-7975

Narrowband Underwater Laser and Detector:

Selective Filtering for Narrowband Detection of Optical Communications Signals

H. H. Caspers and H. E. Rast, Jr.

Selective filtering of optical communication signals may be provided by a fluorescent medium of a certain bandwidth. The medium is insensitive to much of the noise incident upon it, but absorbs and reradiates the signal in the form of fluorescence. A number of materials were tested for suitability for this application.

The objective of this task is to examine the possibility of achieving narrowband, selective filtering of optical communications signals in the blue-green spectral region. The basic concept requires the detection of an optical signal of spectral bandwidth $\Delta\nu_s$ accompanied by noise of bandwidth $\Delta\nu_n$. If the signal-plus-noise is incident on a fluorescent medium having an absorption bandwidth of $\Delta\nu_a$, an improvement is made in signal-to-noise ratio if $\Delta\nu_s \leqslant \Delta\nu_a < \Delta\nu_n$. This improvement, which is approximately $\Delta\nu_n / \Delta\nu_a$, occurs if the medium absorbs the optical signal and reradiates the absorbed optical power in the form of fluorescence. Most materials emit fluorescence at longer wavelengths than the wavelength of the exciting energy and hence can effect isolation of absorbed and fluorescence emission by means of sharp-cutoff filters.

The halogen gases, I_2, Br_2, and solutions of these in various solvents were investigated. Strong resonant fluorescence of molecular iodine excited with 5145-Å radiation of an argon laser source has been observed. Also, crystals and various solvents containing trivalent terbium have been examined. Because of the coincidence of the 4880-Å argon laser transition with the electronic energy levels of Tb^{3+} ($^5D_4$), strong, intense fluorescence at 5500 Å is observed. Crystals of LaF_3:Tb^{3+} and $TbCl_3$ in various solvents are being examined for possible use as wide-aperture, narrowband filters. Experiments are presently being conducted to determine the external quantum efficiency of the various materials discussed.

ZR011.07
(NELC Z198)

Contact:
E. J. Schimitschek, H. H. Caspers, or H. E. Rast, Jr.
Code 2500 or 2600
(714) 225-7975 or 225-6591

Optical Covert Communications Using Laser Transceivers [OCCULT]

G. C. Mooradian

The Optical Covert Communications Using Laser Transceivers (OCCULT) program was started in FY71 under the IED program. It was conceived to meet the Navy's need for a covert communication system between ships and ship to shore that is highly immune to jam, intercept, and spoof and has, in addition, a high data rate. During that year a system for land-based tests over an 11-nmi stretch of water was designed and constructed.

The basic OCCULT system initially consisted of two transceivers for point-to-point communication. Each transceiver had two CO_2 lasers, one a transmitter with output power of about 5 watts, the other a local oscillator with output of about 1 watt. The local oscillator provided a means for translating the information to a frequency more easily worked with—the function it serves in any heterodyne system. This was accomplished by combining the received and local oscillator signals in a square-law detector. The detector used in the OCCULT system was a mercury-cadium-telluride (HgCdTe) device, which must be cooled to liquid nitrogen (77K) temperature at present.

In FY71–FY73, this project was sponsored by the Naval Ship Systems Command under 62752N SF21.222.002 (NELC B807). In November 1972 ship-shore communication (voice and data) was demonstrated (demonstrating pointing, tracking, and acquisition capability from ships). Following this, equipment needed for additional tests was designed, the optical package was contracted, the receiver processing electronics and the pointing system were constructed, and testing was begun at NELC.

In March 1974 the Director of Naval Laboratories provided IED funds to complete the Advanced Development Model. This has been done. On completion of ship-to-ship tests in September 1974 a detailed report will be written.

PUBLICATIONS

Mooradian, G. C., "A 10.6μ Video Bandwidth Acousto-Optic Modulator," *Applied Optics* (to be submitted)

ZF61.212
(NELC Z275)

Contact:
G. C. Mooradian
NELC Code 2500
(714) 225-7975

Publications and Presentations

External Publications

INDEPENDENT RESEARCH

Bromley, K., "An Optical Incoherent Correlator," *Optica Acta,* v 21, n 1, p 35–41, January 1974

Davis, N. M., and Wieder, H. H., "Infrared Scanning Cathodoluminescence Apparatus and Applications," *IEEE-IAS Conference Record,* Milwaukee, Wisconsin, October 11, 1973

Hart, A. R., McQuitty, D. W., and Wagner, N. K., "RF Susceptibility of Microelectronic Components," *Naval Research Reviews,* v XXVII, p 12–16, May–June 1974

Hopkins, R. U. F., and Paulson, M. R., "Equatorial Scintillation," *Naval Research Reviews,* v XXVII, p 17–24, May–June 1974

Lile, D. L., and Davis, N. M., "Semiconductor Profiling using an Optical Probe," August 1974 (to be submitted for publication)

Powers, J. P., "Analysis of a Multipurpose Electro-Optical Signal Processor," Naval Postgraduate School Report NPS-52P07411A

Rubin, D., "Measurement of Gunn Diode Parameters at Millimeter Wave Frequencies," *IEEE Transactions on Microwave Theory and Techniques* (submitted for publication)

Schimitschek, E., Trias, J., Hammond, P., and Atkins, R., "Laser Performance of Fluorinated Coumarin Dyes," *Opt. Comm.* (accepted for publication)

Wieder, H. H., "Transport Coefficients of InAs Epilayers," *Applied Physics Letters,* August 15, 1974 (in press)

White, C. T., "Bioelectronics Research at NELC," *Naval Research Reviews,* v XXVII, p 31–36, May–June 1974

Zeisse, C. R., and Fisher, H. D., "The Measurement of Optical Transfer Function in Imaging Devices that Sample a Scene" (to be published)

INDEPENDENT EXPLORATORY DEVELOPMENT

Bocker, R. P., "Matrix Multiplication Using Incoherent Optical Techniques," *Applied Optics,* v 13, n 7, p 1670–1676, July 1974

Bocker, R. P., Bromley, K., and Monahan, M. A., "Optical Data Processing for Fleet Application," *Naval Research Reviews,* v XXVII, p 44–48, May–June, 1974

Bromley, K., Monahan, M. A., and Bocker, R. P., "CCD Performs Scanning in Optical Processor," *Applied Optics* (to be submitted for publication)

Doherty, D. W., "Modularized Digital Control," *Naval Research Reviews,* v XXVII, p 37–43, May–June 1974

Edmondson, G. D., "A Time-Domain Waveform Display/Analyzer for Speech Research," Naval Postgraduate School, Monterey, California, June 1974 (master's thesis)

Marto, P. J., and Kelleher, M. D., "The Thermal Performance of Air-Cooled Circuit Boards used in Standard Electronic Package Designs," Naval Postgraduate School NPS-59Mx74051, 20 May 1974

McCall, D. C., "Data Compression Using Walsh Transform Source Encoding," *Naval Research Reviews,* v XXVII, p 49–56, May–June 1974

Mooradian, G. C., "A 10.6μ Video Bandwidth Acousto-Optic Modulator," *Applied Optics* (to be submitted)

In-House Publications

INDEPENDENT RESEARCH

Celto, J., Schimitschek, E., and Trias, J., "Voice Communication with a Flashlamp-Excited Blue-Green Dye Laser," NELC TN 2672, 24 April 1974*

LaBahn, R. W., "Recent Experiments Exploring the Properties of F-Region Irregularities that Give Rise to Spread-F and Scintillations," NELC TR 1896, 11 October 1973

Major, R. W., "A Compendium of Satellites for Atmospheric, Ionospheric and Magnetospheric Research," NELC TN 2564, 19 December 1973

Major, R. W., "Consideration of World-Wide Scintillation Prediction Techniques," NELC TN 2501, 18 October 1973

Paulson, M. R., "Status of Scintillation and Spread-F Research," NELC TN 2669, 22 April 1974

Salisbury, G. C., "Location of Shipboard Topside Interference Sources by Photomodulation," NELC TR 1886, 3 August 1973

Strand, T. C., and Persons, C. E., "Incoherent Optical Correlator for Active Sonar," NELC TR 1887, 27 July 1973

Symanski, J. J., Lagnado, I., and Keefer, R. L., "Charge Coupled Devices (CCDs) in Navy Memory Applications," NELC TR (in preparation)

Wieder, H. H., and Tomlinson, J. L., "Magnetic Bubble Domain Computer Memory Components," NELC TN 2598, 29 January 1974

---

*NELC TNs are informal documents intended for use chiefly within NELC

INDEPENDENT EXPLORATORY DEVELOPMENT

Bayless, T. H., "A Distributed Processing Concept for Small Ship Command Control—Expected Payoffs and Risks," NELC TN (to be published)

Christy, D. O., "A Phonemic Vocoder Design," NELC TN (in preparation)

Christy, D. O., "Technical Trade-offs in a Phonemic Vocoder Design," NELC TN (in preparation)

Dillard, G. M., and McCall, D. C., "Discrete Transform Techniques Applied to Signal Processing," NELC TN 2698, 20 May 1974

Glavas, X. G., and True, R. F., "Standard Packaging Designs User's Manual," NELC TD (in preparation)

Lebduska, R. L., and Holma, G. M., "Fiber Optic Cable Hardware Test," NELC TR 1900, 11 December 1973

Leffler, R., "Telecommunications Equipment Low-Cost Acquisition Method (TELC 'M)," NELC TD 335, 15 July 1974

McCall, D. C., "3 to 1 Data Compression Via Walsh Transform," NELC TR 1903, 10 December 1973

Pasahow, E. J., "Alternative Microprocessor Configuration Study," NELC TN 2711, 12 June 1974

Pasahow, E. J., "A Simulation of the Small Ship Command Control System," NELC TN 2725, 27 June 1974

Pasahow, E. J., "Small Ship Command Control System—System Description," NELC TD 318, June 1974

True, R. F., "Heat Transfer Rates of Printed Circuit Boards used in Standard Packaging Designs," NELC TN (in preparation)

Wills, J. R., "Computer Programs for the Phonemic Vocoder," NELC TN (in preparation)

(A NELC TN on OCCULT will be written on completion of sea testing.)

Presentations to Professional Meetings

INDEPENDENT RESEARCH

Bromley, K., "Incoherent Optical Data Processing," Optical Society of America, 9–12 October 1973, Rochester, New York

Hopkins, R. U. F., and Paulson, M. R., "On Equatorial Scintillation," International Union of Radio Science (URSI), Boulder, Colorado, August 1973

Hopkins, R. U. F., and Paulson, M. R., "Space Diversity for Alleviation of Equatorial Scintillation Effects," National Telecommunications Conference, San Diego, California, December 1974

Lagnado, I., NELC, and Whitehouse, H. J., NUC, "Signal Processor Image Sensor Using CCD's," to be presented to the 1974 CCD Application of Technology Conference, Edinburgh, Scotland, 25–27 September 1974

Lagnado, I., NELC, and Whitehouse, H. J., NUC, "Concept of a Signal Processing Imager Using CCD," 1973 CCD Applications Conference, San Diego, California, 18–20 September 1973

Lile, D. L., and Davis, N. M., "Photovoltaic InSb MOS Array," Infrared Information Symposium, El Toro, California, March 1974

Miller, S. A., seminars on the spin-flip Raman laser at the Physics Departments of Louisiana State University, Naval Postgraduate School, and the University of California at San Diego

Monahan, M. A., seminar on "Optical Processing Techniques," San Diego Chapter of the Optical Society of America, 24 April 1974

Saul, D., "Wideband ehf Microstrip Components and the IFM Discriminator," Millimeter Wave Techniques Conference, San Diego, California, March 26–28, 1974

Wagner, N. K., Hart, A. R., and McQuitty, D. W., "Auger Electron Spectroscopy Applied to Reliability Problems in Microelectronic Process Control," Government Microelectronics Applications Conference, Boulder, Colorado, 23 June 1974

Wagner, N. K., and McQuitty, D. W., "Auger Electron Spectroscopy for Analysis of Integrated Circuits," to be presented to the National Electronics Conference, Chicago, Illinois, 16 October 1974

INDEPENDENT EXPLORATORY DEVELOPMENT

Bromley, K., "Signal Processing with Incoherent Light," Gordon Research Conference on Coherent Optics and Holography, 24–28 June 1974, Santa Barbara, California

Christy, D. O., invited to participate in preparing for the NATO-RSG-4 Cooperative Research on Automatic Speech Processing and Recognition Meeting, August 1975

Mooradian, G. C., "Atmospheric and Space Optical Communications," IGC Conference on The Future of Optical Communications, Boston, Massachusetts, 25–28 August 1974

Patent Activity

Independent Research

PATENTS ISSUED

M. Geller, D. E. Altman, and G. J. Barstow

A High Intensity Light Source

Novel metal vapor discharge lamps filled with either zinc-xenon or cadmium-xenon are the most efficient optical sources for conversion of electrical energy into the blue-green portion of the spectrum. This development will result in more practical sources for underwater optical systems.

Patent 3,758,805 (Navy Case 53,178) Serial No. 192,857 Filed 27 October 1971 Issued 11 September 1973

PATENT APPLICATIONS FILED

H. E. Rast and H. H. Caspers

Large-Aperture, Narrowband Detectors for Optical Communication Systems

A narrowband optical detector for Naval covert optical communication signals. An enclosure containing a gas for absorbing and reemitting all photons at the frequency of the signal to be detected. A detector of the photomultiplier type is positioned to receive the reemitted energy.

Navy Case 56,124 Serial No. 375,422 Filed 2 July 1973 Pending

R. E. Potter

Dual-Mode CRT Screen

A dual phosphor screen consists of a mixture of a phosphor having a medium or long persistence emitting in the ultraviolet and a short-persistence green phosphor. The system then provides for electronic switching from long-persistence mode to short-persistence mode and will make possible improved displays for Naval command control systems.

Navy Case 56,482 Serial No 473,987 Filed 28 May 1974 Pending

H. E. Rast and H. H. Caspers

Dye Laser Transmitter - Resonant Fluorescent Detector System for Underwater Optical Communications

The detector is arranged so that the signal is incident at right angles to the stream of molecules of a resonance detector material such as sodium and a photo detector or observer is mutually perpendicular to both signal and beam. Use of detector will improve covert underwater communications.

Navy Case 55,265 Patent application forwarded Patent Office 30 July 1974 Pending

AUTHORIZED INVENTION DISCLOSURES

H. E. Rast and H. H. Caspers

Dual-Mode Display Element for use under Varying Ambient Illumination

An SiO_2 insulating layer is overlayed on a conducting glass substrate. The layer has a portion removed, and this area is filled in with an electroluminescent phosphor. The phosphor and SiO_2 insulator are overlaid with a thin transparent electrode. A liquid crystal is sandwiched between the above assembly and a conducting glass electrode. Under high ambient light conditions, high contrast and visibility exist by means of the dynamic scattering from the liquid darkness. A switch is activated to place the AC potential across the phosphor and produce an illuminated background against which the liquid crystal alphanumeric character may be read in darkness or low ambient light. This dual-mode element may be used in improved displays for Naval command control systems.

Navy Case 57,008 Authorized for preparation of patent application 20 March 1974

D. L. Saul

Improved Millimeter Waveguide to Microstrip Transition

An improved means of transferring guided electromagnetic signals from dominant mode rectangular waveguide to microstrip transmission line at frequencies extending into the millimeter wave region. The initial development was done for the 26.5–40-GHz frequency band but the design can be scaled dimensionally to cover higher or lower bands. This will result in improved radar systems for the Navy.

Navy Case 57,530 Authorized for preparation of patent application 21 June 1974

R. P. Bocker, K. Bromley, M. A. Monahan, and L. B. Stotts

Electro-Optical Spectrum Analyzer

An electro-optical device capable of performing a one-dimensional finite Fourier transform on temporal signals in real time. The device is also capable of performing matrix multiplication of a one-dimensional column vector by a two-dimensional matrix, yielding a one-dimensional column vector. It will give an increased signal processing capability.

Navy Case 56,834 Authorized for preparation of patent application 3 July 1974

I. Lagnado, NELC, and H. J. Whitehouse, NUC

Signal Processing Imager Array Using Charge Transfer Concepts

The charge coupled device (CCD) has the main attribute to handle analog signals with the controllability of digital circuits. It has, however, been used to perform one function (i.e., image sensing, storing data for memory application or processing information). The novelty of the invention is to combine the properties of signal processing and image measurement in a single charge transfer device to perform convolution and correlation. The integration of dissimilar functional operations in a single device reduces hardware duplication, simplifies system implementation, reduces maintainability costs, and improves performance and reliability (by the mere fact of reducing complexity).

Navy Case 56,691 Authorized for preparation of a patent application 25 November 1973

INVENTION DISCLOSURES SUBMITTED

D. L. Saul

Miniaturized Millimeter Wave Instantaneous Frequency Discriminator

A discriminator, in some suitable form, is a key part of an instantaneous frequency measuring (IFM) receiver. A receiver of the IFM type has the ability to monitor continuously all frequencies within a designated frequency band, a property very useful for certain types of surveillance operations. The IFM receiver's military and naval use has become widespread at microwave frequencies up to 18 GHz.

Navy Case 57,804 Disclosure submitted to NELC Patent Counsel 20 February 1974

H. E. Rast and H. H. Caspers

Wide-Aperture Optical Communications Detector

Most narrowband detectors are confined to a small aperture or field of view due to the necessity of using filters which require normal incidence and, hence, narrow field of view. This invention depends for its filtering action on an entirely different principle, thereby allowing large apertures and narrowband detection over a wide field of view. Its use will provide improved surveillance systems.

Navy Case 58,110 Disclosure submitted to NELC Patent Counsel 25 April 1974

Independent Exploratory Development

PATENTS ISSUED

V. N. Smiley, A. L. Lewis, and D. K. Forbes

Method of Producing a Thin Film Laser

A method of producing a laser material by depositing recrystallized material on an unoriented substrate. It is a more practicable method for producing thin-film lasers because thickness and lateral dimensions can be accurately controlled.

Patent 3,787,234 Navy Case 49,107 Serial No. 842,916 Filed 18 July 1969 Issued 22 January 1974

E. J. Schimitschek and J. A. Trias

A Liquid Laser Solution Formed with a Neodymium Salt in Phosphorus Oxychloride

An improved liquid lasing solution which does not deteriorate with time nor as a result of flash excitation. It will result in improved lasers for various systems.

Patent 3,779,939 Navy Case 48,148 Serial No 111,128 Filed 29 January 1971 Issued 18 December 1973

L. J. Johnson

Microminiature High-Efficiency Power Supply

A microminiaturized power supply using open-loop voltage regulation with pulse width control.

It can be used in all electronic circuits requiring a low-voltage power source.

Patent 3,806,791 Navy Case 54,521 Serial No 312,068 Filed 4 December 1972 Issued 23 April 1974

V. N. Smiley

Wide-Range Continuously Tunable Thin-Film Laser

A thin-layer laser of mixed crystal composition with a gradient in composition along one direction in the plane of the layer so that varying the position of the pump energy varies the frequency over a range of 1000 Å. It will be valuable as a tunable, multichannel source for short-range optical communication systems.

Patent 3,747,021

CLAIMS ALLOWED, PENDING ISSUE

P. L. Writer and M. L. Schiff

Surface Wave Narrow Bandpass Filter

In bandpass filter feedback loops, surface wave devices comprising aluminum fingers deposited on a piezoelectric substrate are employed to provide transmission characteristics which invert a transmission null into a bandpass. They may be used to provide improved filtering for Naval electronic equipments.

Navy Case 55,701 Serial No 372,560 Filed 22 June 1973 Claims Allowed, Pending Issue

K. Bromley

Multichannel Optical Correlator System

A high-speed, multichannel optical correlation system employing noncoherent light It will result in improved signal processing

Navy Case 53,266 Serial No 234,749 Filed 15 March, 1972 Claims Allowed, Pending Issue

PATENT APPLICATIONS FILED

R. L. Lebduska

Fiber Optic Cable Connector

A fiber optic cable connector of identical halves which press-fit together, with the terminals spring loaded to maintain the highly polished cable ends in close contact. A ferrule is provided to maintain the cable ends in perfect alignment and to act as a reservoir for the liquid that may be inserted between the cable ends to enhance optical transmission. Fiber optics will have increasing use in Naval communication and data transfer systems.

Navy Case 56,390 Serial No. 437,428 Filed 28 January 1974 Pending

J. J. Symanski and R. H. Ebert

Multi-Wire Cable to Coaxial Cable Transition Apparatus

A cable connector including logic circuitry to perform parallel to serial to parallel functions reducing need for multiple parallel data lines. Use of the connector will improve Naval data transfer systems.

Navy Case 54,948 Serial No. 433,039 Filed 14 January 1974 Pending

D. N. Williams

Fiber Optic To Electronic Interface

A new fiber optic-to-electronic interface circuit which will improve Naval communication and data transfer systems.

Navy Case 55,085 Serial No 449,814 Filed 11 March 1974 Pending

H. F. Taylor and A. L. Lewis

Broadband Optical Coupler

An optical coupler for introducing light signals into an optical data bus and also picking off signals from such a data bus. It will improve Naval data transfer systems.

Navy Case 55,909 Serial No 469,199 Filed 13 May 1974 Pending

R. L. Lebduska

Method and Apparatus for Detecting Individual Fiber Breakage in Multifiber Optic Cables

A method of assessing the individual fiber breakage in a bundle of fiber glass fibers. The terminated ends are illuminated and viewed through a microscope. The broken fibers appear as black circular elements. Fiber optics will have increasing use in Naval communication and data transfer systems.

Navy Case 56,533 Serial No 445,406 Filed 25 February 1974 Pending

L. B. Stotts

Improved Optical Transmit-Receive Coupler

A liquid crystal grating for coupling light into fiber optics. This will improve Naval communications and data transfer systems

Navy Case 55,645 Serial No 457,007 Filed 1 April 1974 Pending

K. Bromley

Correlation Using Charge Coupled Devices

A system using charge coupled devices to permit parallel optical correlation processing in real time. It will improve Naval signal and data processing systems.

Navy Case 56,119 Serial No 484,832 Filed 1 July 1974 Pending

L. B. Stotts and W. M. Caton

Improved Birefringent Optical Coupler

An optical coupler for waveguides employing the birefringence properties of nematic liquid crystals as indiced and controlled by an electric field. It will improve Naval Communications and data transfer systems.

Navy Case 56,018 Serial No. 456,692 Filed 1 April 1974 Pending

L. B. Stotts

Improved Optical Coupler

A passive optical coupler employing the distinctive wavelength sensitivity and polarized directional responsivity of different cholesteric liquid crystal materials to selectively couple out optically transmitted data and information from a common optical bus. It will enable improved data and information transfer systems to be built.

Navy Case 56,703 Serial No. 465,962 Filed 1 May 1974 Pending

H. K. Landskov

Polypole Broadband Antenna Array

An effective, simple, and inexpensive broadband antenna array for small ships and light vehicles and comprising a plurality of like monopoles placed in either a triangle or quadrangle configuration with a monopole at each apex. It will make possible an increase in available communications channels with smaller and lighter antennas.

Navy Case 55,647 Serial No. 423,339 Filed 10 December 1973 Pending

C. Nuese

Block Coded Communication System

A noisy forward communication channel is employed to transfer data which have been symbolically coded and also to transfer correction instructions; a noiseless feedback channel is used to return each symbol as it is received to the sending station. The apparatus transfers binary digital data without excessive redundancy, delay, or complexity by correcting transmission errors by means of correction instructions as opposed to retransmitting the entire block of data.

Navy Case 54,605 Serial No 425,580 Filed 17 December 1973 Pending

AUTHORIZED INVENTION DISCLOSURES

A. Roth and G. M. Holma

Closest Point of Approach Calculator

A manually operated, programmed (dedicated) calculator that computes the range, bearing, and time of closest point of approach of any or all of five selected target ships, and also their course and speed. Its use will be valuable in reducing collisions and casualties

Navy Case 56,072 Authorized 29 January 1974 for preparation of patent application

L. J. Johnson

Power Supply

An electronic power supply apparatus for use with a wide range of input voltages. A series switch type regulator is caused to regulate at two voltages (65 and 8 volts). This is done by sensing the regulated voltage and, by means of gate circuits, switching from one mode of regulating to the other without loss of efficiency. This technique enables provision of more efficient and lighter weight power supplies for Naval electronic systems.

Navy Case 56,508 Authorized for preparation of a patent application 17 January 1974

J. A. Cocci and M. L. Schiff

PCM Synchronization and Multiplexing System

The invention comprises apparatus for obtaining transmitter-receiver synchronization in an audio transceiver which employs pulse code modulation. The apparatus also provides demultiplexing of time multiplexed signals on the same data channel. The main advantage of the apparatus is that only one frame of data is lost for any one sync error. Also, the concept can be implemented reliably and inexpensively by means of conventional digital integrated circuitry. It will result in more accurate and less complicated data transfer systems.

Navy Case 56,908 Authorized for preparation of a patent application 25 February 1974

D. W. Doherty and E. J. Wells, Jr.

Universal Modularized Digital Controller

A miniaturized digital controller for use in a servomechanism system controlled by signals from a computer or other digital data source. It will improve fire control and steering and simplify Navy logistics problems.

Navy Case 55,860 Authorized for preparation of a patent application on 25 J 'y 1974

INVENTION DISCLOSURES SUBMITTED

J. C. Lawrence and A. Roth

Schalkwijk Algorithm

Provides a data compression technique for use with general sources and comprises a direct generalization of run length coding. The technique is also operable with sources of time-varying and nonstationary statistics. It will result in improved secure communications systems.

Navy Case 57,173 Invention disclosure submitted to NELC Patent Counsel 10 September 1973

Active Projects for FY74

Independent Research

NELC Problem	Title	Principal Investigator	NELC Mail Code	AUTOVON	Research Requirement	FY74 Funding $k	DDC Key
Z175	Low-Light-Level TV IR Cathode	Dr. C. R. Zeisse	2600	933-6591	ZR021.03	$ 45	DN 213139
Z192	Equatorial Scintillation Research	R. U. F. Hopkins	2400	933-7767	ZR021.01	55	DN 487547
Z193	Devices for New Frequency Regions	J. W. Carson	2300	933-6763	ZR011.07	235	DN 487534
Z194	Signal Processing Imager Using Charge Coupled Devices	Dr. I Lagnado	4800	933-6877	ZR021.03	50	DN 487535
Z195	Solid-State Materials and Processes Characteristics	C. E. Holland, Jr.	4300	933-6860	ZR011.02	250	DN 487536
Z196	Solid State Mass Memory	J J Symanski	3200	933-6515	ZR021.03	120	DN 487537
Z197	Programmable Electro-Optical Processor	K. Bromley	2500	933-6641	ZR011.12	75	DN 487538
Z198	Narrowband Underwater Laser and Detector	Dr. E. J. Schimitschek	2500	933-7975	ZR011.07	170	DN 487539
Z101	Solvated Electron/Solid System	Dr S J Szpak	2600	933-6591	ZR022.06	10	DN 487641

Independent Exploratory Development

NELC Problem	Title	Principal Investigator	NELC Mail Code	AUTOVON	ED Task Area	FY74 Funding $k	DDC Key
Z268	Voice and Image Data Companding	Dr D O Christy	3200	933-6515	ZF61-212	250	DN 487540
Z269	Telecommunication Equipment Low-Cost Acquisition Method (TELCAM)	C L Ward	4400	933-7295	ZF61-512	230	DN 487541
Z270	Small Ship Command Control System (SSCCS)	D G Mudd	3300	933-6258	ZF61-212	296	DN 487542
Z271	Fiber Optics Tactical Data Link MTACCS	J D Hollabaugh	1700	933-6738	ZF61-212	35	DN 487618
Z272	Advanced Digital Communications Modules System (ADCOM)	B B. Mahoney	3200	933-6515	ZF61-212	100	DN 487543
Z273	C^3 Standard Packaging System	X G Glavas	4400	933-7136	ZF61-212	79	DN 487544
Z274	Electro-Optical Processors	K Bromley	2500	933-6641	ZF61-212	50	DN 487638
Z275	Optical Covert Communications Using Laser Transceivers (OCCULT)	Dr G C Mooradian	2500	933-7975	ZF61-212	150	DN 487639
Z276	VERDIN Demodulator Design Study	W J Dejka	5600	933-2685	ZF61-212	46	DN 487640

Projects Terminated in FY74

Independent Research

NELC Problem	Title	DDC Key	Reason for Termination
Z175	Low-Light Level TV IR Cathode	DN 213139	Improved cathodes of GaSb points were not realized.
Z192	Equatorial Scintillation Research	DN 487547	Funding preempted.
Z193	Devices for New Frequency Regions	DN 487534	Funding preempted; partially funded by 63522N S3643 (NELC G224), "Undersea Warfare Intelligence Support."
Z196	Solid State Mass Memory	DN 487537	Funding preempted.
Z197	Programmable Electro-Optical Processor	DN 487538	6.1 work completed; now in IED 62766N and also planned for NAVELEX 6.2.
Z198	Narrowband Underwater Laser Detector	DN 487539	Funding preempted; partially continued under 62762N XF54.545.033 (NELC F233), "Blue-green Dye Laser Technology."
Z1[illegible]	Solvated Electron/Solid System	DN 487641	Completed.

Independent Exploratory Development

NELC Problem	Title	DDC Key	Reason for Termination
Z268	Voice and Image Data Companding	DN 487540	Funding preempted.
Z271	Fiber Optics Tactical Data Link MTACCS	DN 487618	Analysis complete, cable for field tests being constructed
Z272	Advanced Digital Communications Modules System (ADCCM)	DN 487543	Funding preempted.
Z273	C^3 Standard Packaging Designs	DN 487544	Completed; results being used

Multisponsored IR/IED Projects for FY74

NELC Problem	IR/IED PROJECT			NELC Problem	OTHER FUNDING	
	Title	Funding	Amount		Funding	Amount
Z192	Equatorial Scintillation Research	ZR021.01	$ 55	M221	ONR 61153N RR032-08-0	$ 26
				B215	ELEX 11402N X1508	10
				M207	AIR 62759N WF52.551.701	10
Z274	Electro-Optical Processors	ZF61.212	50	N609	ONR 62721N RF21.242.102	20
Z198	Narrowband Underwater Laser and Detector	ZR011.07	170	F211	ELEX 62721N XF21.222.018	15
Z275	Optical Covert Communications Using Laser Transceivers (OCCULT)	ZF61.212	150	S202	NIF (NOL--NSAP)	150

Projects for FY75

Independent Research

NELC Problem	Title	Principal Investigator	NELC Mail Code	AUTOVON	Research Requirement	FY75 Funding $k	DDC Key
Z194	Signal Processing Imager Using Charge Coupled Devices	Dr. I. Lagnado	4800	933-6877	ZR021.03	$ 50	DN 487535
Z195	Solid-State Materials and Processes Characteristics	N. K. Wagner	4800	933-6877	ZR011.02	450	DN 487536
Z102	Indium Phosphide Diagnostics and Devices	H. H. Wieder	2600	933-6591	ZR021.02	70	DN 587501
Z103	Advanced Integrated Material for Power Electronics Reliability	L. J. Johnson	4300	933-7919	ZR021.03	100*	DN 587502
Z104	Integrated Optical Processing	Dr. H. F. Taylor	2500	933-6641	ZR011.12	100	DN 587503
Z105	Intercept and Identification of Spreading Spectrum Signals	R. A. Dillard	3300	933-6257	ZR021.00	60	DN 587504
Z106	Statistical Logic	W. Carper	3500	933-6227	ZR021.03	50	DN 587505
Z107	Continuous Blood Pressure Monitoring	Dr. J. Silva	3400	933-6471	ZR041.01	50	DN 587506
Z108	Frequency Shaping for Voice Communications	C. R. Allen	3400	933-7372	ZR021.03	25	DN 587507
Z109	Human Decision Making as a Function of Display Composition Variables	Dr. R. A. Fleming	3400	933-7372	ZR042.09	50	DN 587508

Independent Exploratory Development

NELC Problem	Title	Principal Investigator	NELC Mail Code	AUTOVON	ED Task Area	FY75 Funding $k	DDC Key
Z269	Telecommunication Equipment Low-Cost Acquisition Method (TELCAM)	J. H. Townsend	4400	933-7296	ZF61-512	$325K	DN 487541
Z270	Small Ship Command Control System (SSCCS)	D. G. Mudd	3300	933-5258	ZF61-212	40	DN 487542
Z274	Real-Time Mask for Electro-Optical Processor	R. P. Bocker	2500	933-6641	ZF61-212	100	DN 487638
Z275	Optical Covert Communications Using Laser Transceivers (OCCULT)	R. November	2020	933-6281	ZF61-212	75	DN 487639
Z276	OED Validation using V[illegible]N Receiving System	A. L. Heaberlin	2100	933-6856	ZF61-212	48.5	DN 587640
Z277	Tactical Data Network	R. E. Kelly	3200	933-6515	ZF61-212	355	DN 587500
Z278	USMC Tactical Communications Automatically Tuned VHF Inline Filter	J. E. Kershaw	2100	933-7701	ZF61-512	60	DN 587509
Z279	USMC Tactical Communications Program Tactical HF Modems	G. A. Clapp	2100	933-7146	ZF61-212	20	DN 587510
Z280	USMC Intelligence Program LWBSR Modulation and Coding	L. H. Bossert	2300	933-6560	ZF61-112	40	DN 587511
Z281	MC Tactical Communications Message Entry Device	R. E. Kelly	3200	933-6515	ZF61-512	20	DN 587512